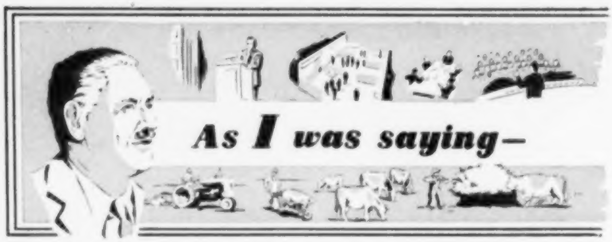
METAL PROGRESS

IN THIS ISSUE

Printer's type gave F. Bjerstedt his inspiration for a first prize cover in the competition at Cleveland School of Art.

• See ***Bill's Column***

on the other side



SAILING ON THE 80,000-ton Queen Elizabeth is just the same as attending a cocktail party for six continuous days — and to add insult to injury I did not drink and did not even fall off the wagon. What a wagon!

It was a grand send-off our friends in the U.S.A. gave us, with packages, presents, letters, wires, candies, fruits, flowers, and bundles of well-advertised brands. With many friends at dockside, our stateroom had the effect of the usual Metal Show "S.R.O.", and we could easily have stocked the cabin steward if he wished to open a general store on shipboard. But it was wonderful to be remembered, and all those send-offs condition you to enjoy the trip.

At noon the "all ashore" sounds for departure. The big ship backs into the river, the tugs turn her around and she heads down the river. You wave goodbye to friends long after you realize they couldn't distinguish you from the captain on the bridge.

To make the trip memorable there were two other old-time ASMers on board — Howard Biers, well-known European representative for Union Carbide & Carbon Co., and George Tall, Jr., top Leeds & Northrup vice-president. George was on a business trip, and Howard on his 139th crossing, combining business with representation of the A.I.M.E. at the same meeting with European technical society representatives that I am to attend.

After the first night you dress for dinner (black tie) and begin the following routine:

7:30 — Awakened by steward with coffee tray. 8:00 — Brisk walk around the deck (2½ times equals one mile). 9:00 — Breakfast (all meals are from soup to nuts). 10:30 — Reading, deck chairs, swimming or table tennis. 11:45 — Bouillon and biscuits (wherever you are). 12:30 — Meeting with Harold, major domo of the Forward Lounge (bar), at a special table known as "The Nest". 1:30 — Luncheon ("The fillet mignon is delicious today"). 2:30 — Play cards or sit on deck — musicale in the main lounge. 4:00 — Tea and sweets. If you are not where you are supposed to be they'll find you because you must have your tea. 5:00 — With warm tea in you and a strong breeze coming through the porthole I defy you to do anything but rest and sleep in preparation for what's to come. 7:30 — Meeting (again) with Harold in the fo'cas'le (I'm a sailor now). 8:30 — Dinner (soup, fish, meat, salad, dessert, coffee).

At dinner the first evening the wine steward who parades in the dining room (called restaurant) with the key to the cellar came to table 53 and said, "Mr. Eisenman, I have in my cooler seven bottles of champagne that have been ordered for your pleasure by friends in the States. Here are their cards. Do you wish me to serve one now?" I'll let you, Mr. Reader, answer that question.

9:40 — Movie (a good short and a new long one). 11:30 — Dancing in the main lounge — light (or heavy) refreshments. 12:30 A. M. — Adjourn to the night club on top deck with fine orchestra, good dance floor, fewer people but good giggle water (1945 vintage) and free sandwiches. On Saturday night I stayed in the club until 4:00 a.m. and then snuck to bed (and slept most of the next day and was thrown helter-skelter off the schedule I've given you).

But you must know of one flying experience my pj's had. When I retired the first evening I naturally looked for the chute to throw my soiled linen to the basement. I saw a round window that looked exactly like the Laundromat at home. It had a W on it, and I thought to myself "You can be sure if it's ——" (plug) and opened the Laundromat door and put the pj's to soak. The last I saw of them the pants were waving hello to the sharks and floating to the sky. The next evening at cocktails in the purser's quarters he related how a beautiful, delectable and delorious blonde was standing on the top deck when from out of thin air came a pair of waving pajama pants and wound their legs around her neck, causing her some confusion. So that's the way "you can be sure — if" you want 'em back.

Cordially yours,

Bill

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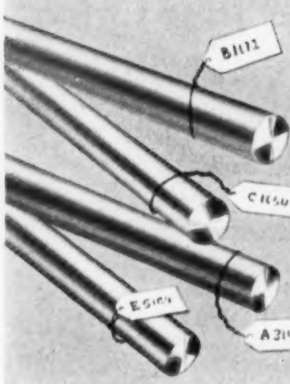

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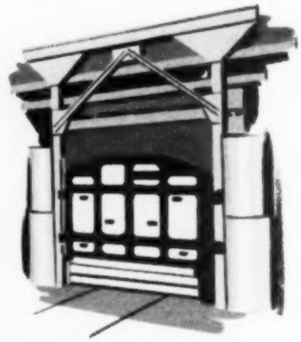

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ALUNDUM* (fused alumina) is an electric furnace product made from bauxite. It is alumina in its most dense and unshrinkable form. Alundum is a chemically inert material of high refractoriness, electrical resistivity, thermal conductivity and it is chemically stable.

CRYSTOLON* (silicon carbide) is an excellent heat conductor and is highly resistant to spalling and to slag adherence and penetration.

MAGNORITE*(fused magnesia) is one of the most refractory oxides available commercially. It is resistant to basic slags and is used principally for lining induction furnaces in which refractory

metals and alloys of both ferrous and non-ferrous types are melted.

FUSED STABILIZED ZIRCONIA is a Norton "first" in research. No other refractory offers such an unusual combination of properties. It has both amazing resistance to high temperature (up to 4700°F) and extremely low thermal conductivity. It is chemically inert in contact with ferrous alloys.

Some R Examples for different needs

For high frequency induction furnaces to melt more steel per lining, it's Norton MAGNORITE cements for melts ranging from straight steel to heat-resistant combinations. Made specifically to be dry-rammed. MAGNORITE crucibles in various compositions available for smaller furnaces.

For indirect arc furnaces, foundries get fine results with ALUNDUM or MAGNORITE crocks, covers, and cements of the right specification.

For low-frequency furnaces, choose ALUNDUM or MAGNORITE, depending on the metals or alloys you are melting such as cupro-nickel and nickel-silver, high copper alloys and Al, Te, and Si bronzes. Both have the high-rammed density that resists metal penetration, erosion and chemical attack.

In back-slagging cupolas, CRYSTOLON slag hole blocks resist slag action 5 to 15 times longer than fire clay . . . show little or no signs of softening, spalling or cracking at temperatures as high as 3050°F.

In heat-treating and sintering furnaces, there are ALUNDUM and CRYSTOLON hearth plates, pier brick, muffles, muffle plates, skid rails, recuperator tubes, burner tunnel and embedding cements in various compositions.

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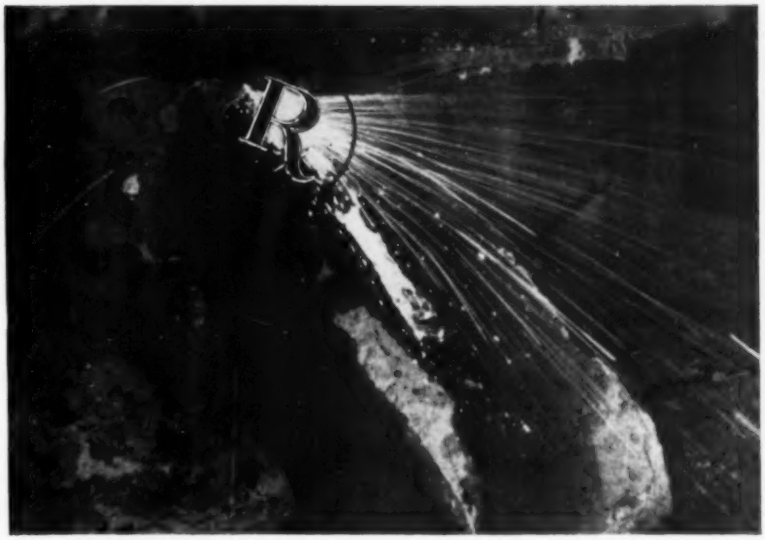
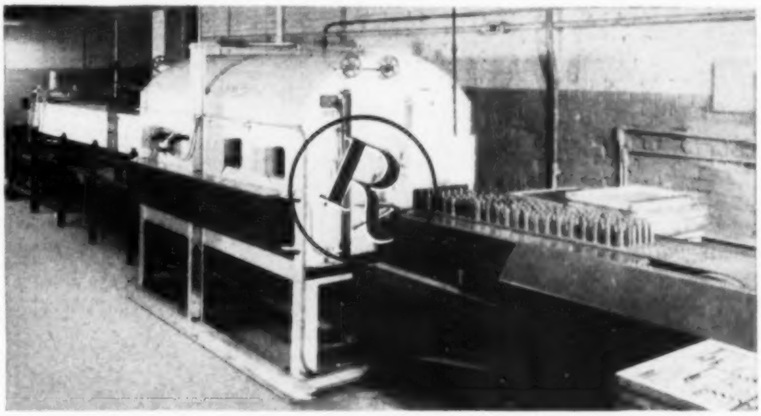


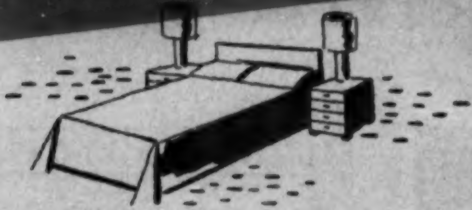
Norton CRYSTOLON slag hole block. Picture shows one of many similar installations in foundries. Users have reported up to 65 hours operation without shutdown.

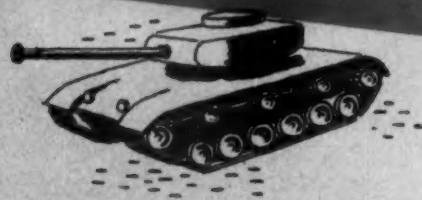


Norton CRYSTOLON hearth tile in this electric furnace is an ideal refractory bed for the conveyor belt. It has an unusually long life.

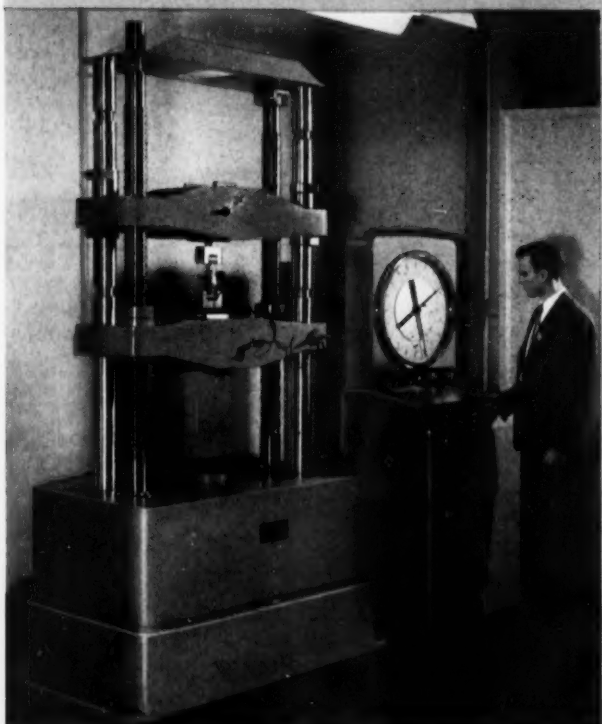
Norton MAGNORITE cement. 1000-lb. high frequency induction furnace after metal has been poured. Note how MAGNORITE cement lining resists mechanical and chemical attack.

FROM BED SPREADS TO TANK TREADS





You can test practically anything with a



Tension test in progress on Riehle 120,000 lb. Hydraulic Universal. Photo courtesy of Cleveland Tank Plant, Cadillac Motor Car Division, General Motors Corporation.

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Riehle Universal Testing Machines are available either with hydraulic loading unit or with screw power loading unit, in all sizes up through 400,000 lbs. capacity. Ask your Riehle representative or write for illustrated catalogs.

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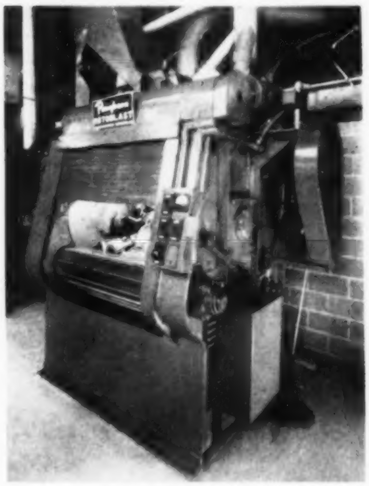
engineering digest OF NEW PRODUCTS

Blast Cleaning

Two new Pangborn Blastmaster barrel sizes (3 and 18 cu.ft.) will include all of the exclusive features of



presently available 6 and 12 cu.ft. sizes. One of the most important of these features is the really abrasive-tight door. This door is of all-metal construction, laminated with a rubber back to protect it from flying abrasive.
For further information circle #1644 on literature request card on p. 32B

Spectroscopic Electrodes

National Carbon Co. is now supplying preformed spectroscopic electrodes in high-purity packages in order to assure the purity until they are

opened in the laboratory. After being machined, the electrodes are purified and are never touched by hands or other possible contaminants after purification. They are packed under spectroscopically pure conditions and hermetically sealed.
For further information circle #1645 on literature request card on p. 32B

Te-Ni-P Bronze

Telnic bronze, a copper-base alloy containing tellurium, nickel and phosphorus, is available from Chase Brass & Copper Co. The physical and electrical properties and the suitability for hardening by heat treatment, hot working or forging without loss of good electrical conductivity are due to the nickel and phosphorus. Good machinability, equal to 80% of free-cutting brass, is obtained by the addition of tellurium. The use of tellurium does not present the disadvantage of hot shortness characteristic of leaded, high copper alloys.
For further information circle #1646 on literature request card on p. 32B

Blackening Compound

A new ferrous metal blackening compound has been introduced by the Du-Lite Chemical Corp. Particularly effective for stainless steels, this compound will produce a nonfading black finish without the need for special equipment. Operating temperatures required for processing are low, the maximum being 240° F.
For further information circle #1647 on literature request card on p. 32B

Silver Brazing Flux

An improved, all-purpose version of its "1200" flux compound has been announced by the American Platinum Works for use in all silver brazing operations. Consisting of a mixture of fluoride and borate salts, the flux melts at a temperature lower than the alloys employed and forms a coating of fused salts over the brazing area. A smooth paste, it is easily removed after brazing by washing with water.
For further information circle #1648 on literature request card on p. 32B

Acid Pickling

The Mitchell-Bradford Chemical Co. has announced the development of a new pickling addition, a chemical solution which is added to hydrochloric, sulphuric and nitric acid pickling solutions to produce a bright, uniform, faster and more economical pickling action with a minimum of attack on base metal. It is added in the proportions of 2½ qt. to 100 gal. of pickling solution.
For further information circle #1649 on literature request card on p. 32B

Universal Microscope

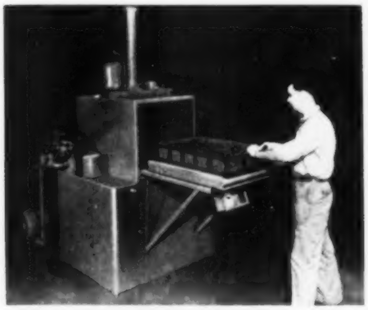
Magnifications from 4 to 3000× can be run with continuity on the ground glass screen of the new ZC Galileo universal microscope. Without re-centering, magnification of any objective set-up can be instantly increased or decreased four times. Macrophotography down to 5× can be done without disturbing specimens. An ingenious tube arrangement with bayonet mounting of accessories for all

techniques permits the observer to make quick changes while studying the specimen. Eyepiece viewing and photographing on both still and movie camera can all be done at the same time. A fourth operation, projection up to

20 ft. on a 40-in. screen, can also be simultaneously performed when transmitted light is used. The instrument provides everything needed for macro and microphotography, polarization, phase, dark-field, oblique and standard microscopy in transmitted and reflected light. It will also do multiple beam interferometry.
For further information circle #1650 on literature request card on p. 32B

Automatic Washer

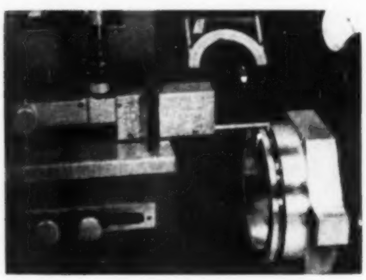
A new line of compact, forced-circulation washers designed to speed



metal cleaning through automatic cycling and by combining washing and rinsing has been announced by Ipsen Industries, Inc. For average load conditions, a total cycle of 5 to 7 min. is sufficient to clean workpieces thoroughly. Solution heating is provided by immersion elements for gas, electric or steam heating. Temperatures are controlled. The units are available in load capacities of 300, 400 and 700 lb.
For further information circle #1651 on literature request card on p. 32B

New Profilometer Tracer

Micrometrical Mfg. Co. announces the Profilometer Type KB Tracer, for measuring surface roughness across the bottom of flat-bottomed grooves to ¼ in. depth and behind shoulders to ¼ in. height. When measuring crosswise, it permits $\frac{1}{16}$ in. length of



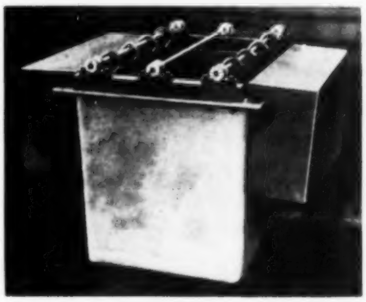
trace in grooves of $\frac{1}{32}$ in. width, and greater length of trace in wider grooves. To permit reaching down into grooves and over shoulders, this tracer has no skids, and the tracer point is at the bottom of a vertical extension at the end of a long beam.
For further information circle #1652 on literature request card on p. 32B

Welding Electrode

A new mild steel electrode of high penetration power has been especially designed for butt and fillet welds in the horizontal position, to be used on steels from 54,000 to 80,000 psi. tensile strength. Economy can be achieved with this Weldwire electrode by elimination of joint preparation of plates up to ¾ in. thick; square butt joints suffice. It can also be used for tack welding and gouging.
For further information circle #1653 on literature request card on p. 32B

Plating Tank

Hanson - Van Winkle - Munning Co. offers a new seamless Fiberglas tank for use with all solutions generally used in the plating field with the exception of caustic cleaner and hydrofluoric acid. Temperatures of tank



contents may be as high as 220° F. Tanks can be custom molded to the exact size desired.
For further information circle #1654 on literature request card on p. 32B

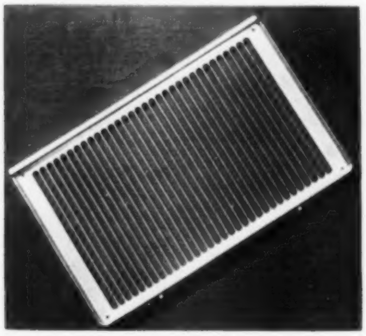
Carbon Brazing Boats

The increasing use of furnace brazing calls for a wide variety of carbon supporting boats or trays to hold the parts in place before the brazing material solidifies. Stackpole Carbon Co. offers a number of designs to which alloys used in brazing will not cause trouble due to sticking.
For further information circle #1655 on literature request card on p. 32B

Aluminum Sheet Alloy

Development of K155, a new aluminum sheet alloy that contains 0.9% magnesium, has been announced by

Kaiser Aluminum & Chemical Sales, Inc. K155 has been used for more than two years in the production-line stamping of louvered refrigerator shelves, and also in such other products as light reflectors, meat trays and

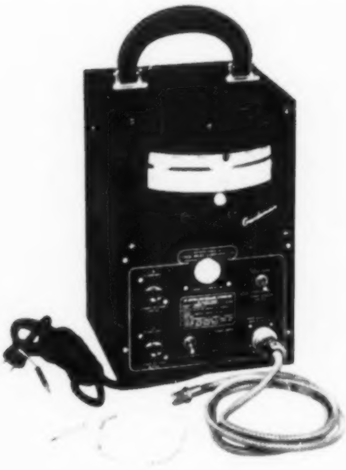


utensils. This new alloy has the same general mechanical properties and prices as alloy 3S. It is well suited for taking anodized finishes, as it shows less tendency toward structural streaking and has a clearer, lighter color after processing, that is free of the yellowish-gray tinge of 3S or the brownish tinge of 52S.

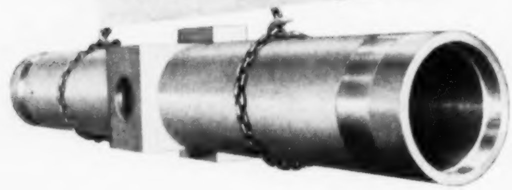
For further information circle #1656 on literature request card on p. 32B

Portable Temperature Controller

The new portable temperature controller by West Instr. Corp. gives precision control by merely plugging the instrument into a wall outlet and plugging the unit to be controlled



into the instrument. Then, by inserting the instrument thermocouple into an oven, bath or thermocouple well, the true temperature is indicated by the upper pointer and may be controlled at any desired point by setting the lower pointer. Two power outlets



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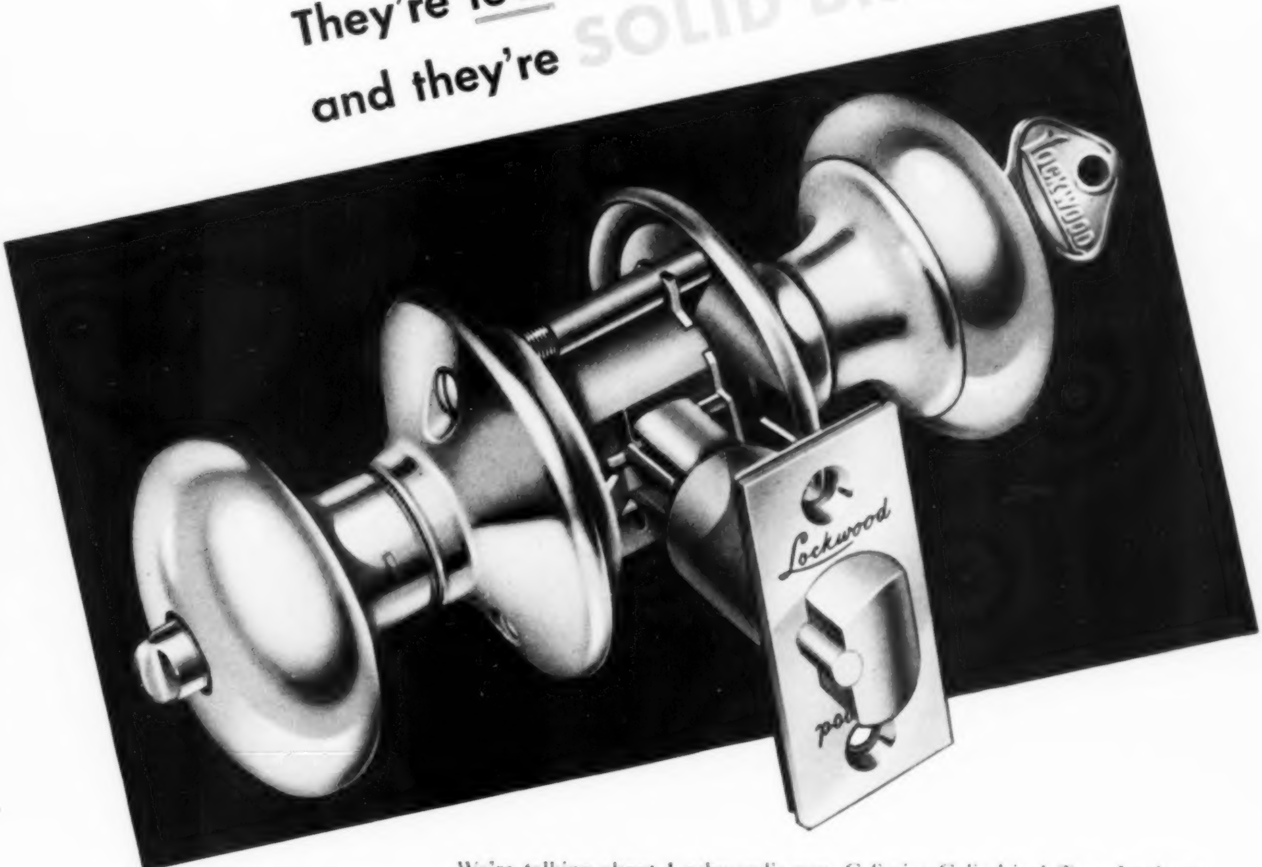

This new C Series Cylinder Type Lockset is made by Lockwood Hardware Mfg. Co., Fitchburg, Mass., Division of Independent Lock Company. Anaconda Metals in a variety of alloys were especially adapted to its "solid brass" construction.

We're talking about Lockwood's new C Series Cylindrical Type Locksets recently introduced to the trade. An entire new plant was built for their production.

Here, for the first time in Lockwood's history, ease-of-installation, ruggedness, smooth operation, outstanding design and long life were engineered into a lockset in one fell swoop, aimed specifically at the low-price field.

Time-tested brass is used in every wear-and-weather-vulnerable spot: turnbutton, knobs, knob shanks and inserts, roses, latchplate, auxiliary locking plunger — right down to the pins, springs, tumblers and extruded shell of the cylinder lock.

It took a bit of doing to determine the right Anaconda Copper Alloy, in just the right temper, gage and grain size for each of the several different functions and fabricating operations involved. But then, that's been the business of The American Brass Company for a long time. Maybe we can be of service to you? Address: The American Brass Company, General Offices, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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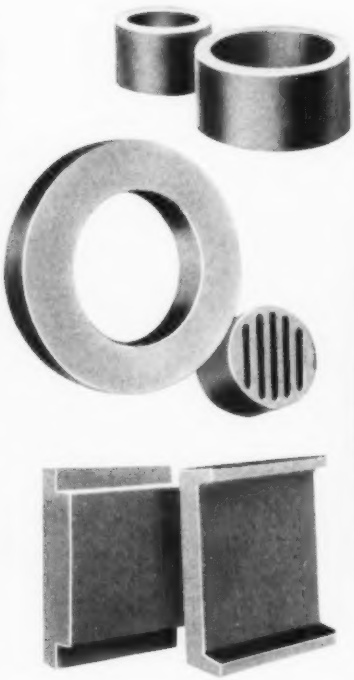

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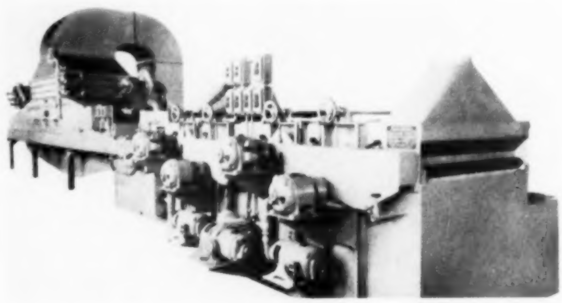
Youngstown, Ohio

enable the instrument to control not only temperature but also blowers, fans, agitators or other mechanisms. All models have a dual range of 50 to 500° F. (iron-constantan) and 0 to 2000° F. (chromel-alumel). The controller is available in three models: on-off, proportioning, and combination high limit and on-off.

For further information circle #1657 on card, p. 32B

Applying Lubricants to Sheets and Blanks

A new Drawcote automatic machine, designed especially for the application of lubricants to sheets and blanks, has been announced by Gilron Products Co. Material can be

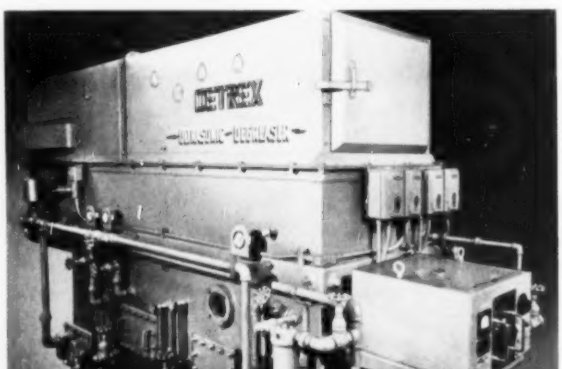


processed through this machine at speeds up to 55 ft. per min. Three separate operations are performed: (1) Sheets or blanks to be coated enter the washer unit, where rotary brushes clean the stock with an alkaline cleaner. (2) Cleaned stock then enters the self-contained coating unit where it is handled in a horizontal position for easy loading and stacking. The steam-heated, fully enclosed solution tanks can handle blanks up to 48 in. wide. (3) After coating, the stock enters the drying element which is available with steam, gas or electrically heated ovens.

For further information circle #1658 on card, p. 32B

Ultrasonic Cleaning

The Detrex Corp. has announced an advanced, practical method of metal cleaning through the use of ultrasonic waves. The new method, known as the Soniclean process, features a new transducer element for directing sound energy. The element is a curved piece of ceramic resembling a 6-in.-long pipe, cut in half along the longitudinal axis. Electrical energy is transmitted to the ceramic transducer, converted into sound energy, and projected through a solvent at a frequency of 430,000 cycles per sec. The



solvent currently being used is trichlorethylene; however, the process is not limited entirely to this material. Because a potential of only 40 volts is required to operate the transducers, they can be safely used in the solvent.
For further information circle #1659 on card, p. 32B

Forging Stock Manipulator

The Manipulet, by Salem-Brosius, Inc., meets the forging industry's demand for a lightweight, low-cost machine for manipulating hot forging stock in hammer or press operations. The unit embodies a new principle in manipulation, furnace charging and drawing, and hot stock handling of forging stock up to 1500 lb. in weight. It converts a standard lift truck into a forging manipulator by incorporating into its design a hydraulically actuated manipulating apparatus. The entire manipulating mechanism is mounted on the elevating track of the lift truck. Hammer operations can sometimes be speeded up by 150% because the use of cranes, slings, and such are eliminated.
For further information circle #1660 on card, p. 32B

Electric Rotary Hearth Furnace

Designed to operate continuously at temperatures to 2500°F., this rotary hearth furnace by Hevi Duty has a rating of 260 kw. with a capacity of 1500 lb. per hr. Silicon carbide rod-type heating elements arranged vertically

can be replaced easily, even while the furnace is hot. A variable-speed drive mechanism can be adjusted for the desired speed of the rotating hearth. Hearth diameter is 7 ft., door opening is 18 in. wide and adjustable between 6 and 10 in. in height. The furnace can be used for scale-free hardening or as a high-temperature forging furnace.
For further information circle #1661 on card, p. 32B

Aluminum Electrodes

Coated aluminum electrodes 2S and 43S grades manufactured by the extrusion process are available from Weldwire Co., Inc. The coating is not hygroscopic. The electrode is used on direct-current reversed-polarity and operates with a stable and quiet arc. Easy arc striking and easy slag removal are characteristic.
For further information circle #1662 on card, p. 32B

Controlling Hot Steel Extrusion

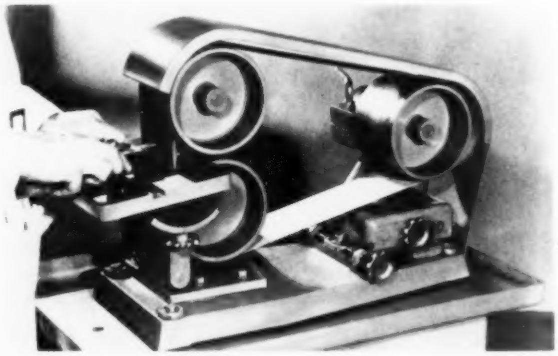
A series of Honeywell radiation devices constitute the heart of the electronic control system which automatically

regulates temperatures during the hot steel extrusion process recently unveiled by U. S. Steel's National Tube Div. In the new French "Sejournet" process the tough stainless steel slugs are first pre-heated in a three-zone gas-fired furnace and then carried by conveyer to a salt bath. The radiation devices, located on the pre-heat furnaces and the salt baths, are in turn connected to a series of electronic recording and controlling instruments.

For further information circle #1663 on card, p. 32B

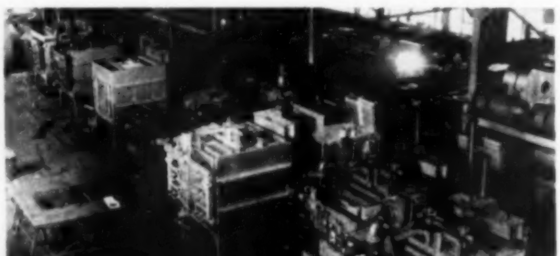
Finishing of Carbide Tools

A new method for final finishing of carbide tools is being introduced by Minnesota Mining and Mfg. Co. and Hammond Machinery Builders. Based on the use of low-cost abrasive paper belts and a new type of belt machine, it will make possible expanded use of carbide cutting tools. Major significance of the new method is that it sim-



plifies the job of carbide tool sharpening. The new method is intended to supplement or replace the conventional diamond wheel method — especially where the initial cost of diamond wheels is prohibitive. A two-step tool sharpening technique is employed: (1) rough grinding on a standard grit 60 silicon carbide wheel, and (2) finishing the sides and top of the carbide tip on an abrasive belt ranging from grit 60 to 150, depending on the edge required.

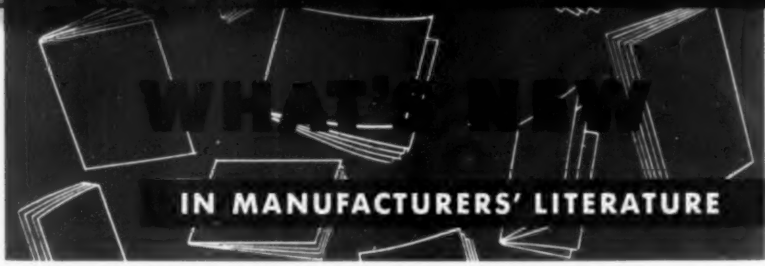
For further information circle #1664 on card, p. 32B



Heat Treat Furnace Production Line

Production-line manufacture of large heat treating furnaces is shown in the accompanying illustration from the Surface Combustion Corp.'s Toledo plant. Six of the new Allcase furnaces are shown. This high-production batch-type unit, equipped with enclosed quench and vestibule, is radiant tube fired for atmosphere control.

For further information circle #1665 on card, p. 32B



1666. Agitator
Data sheet on TurboTube agitator, its advantages and operation. *Chemineer*

1667. Allowable Stresses
Data Card 154 gives maximum allowable stress values for 22 types of steel tubing. Formulas for calculation of maximum working pressures. *Babcock & Wilcox*

1668. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

1669. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

1670. Alloy Hearth
Bulletin 112 on cast Ni-Cr hearth for heat treating furnaces. *Fahralloy*

1671. Alloy Selection
Chart to select alloy for given corrosive problem. 350 corrosives included. *Cooper Alloy Foundry*

1672. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1673. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

1674. Aluminum
Folder on cast aluminum plates and bars for use in tools, dies, jigs and fixtures. *Reynolds Metals*

1675. Aluminum Castings
Bulletin on quality control methods employed in making aluminum castings. *Permold*

1676. Ammonia Atmospheres
12-page Bulletin B-52 on dissociated ammonia for furnace atmospheres. *Drever*

1677. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

1678. Anodizing
Data on aluminum racks with copper hooks for anodizing. *National Rack*

1679. Atmosphere Furnace
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

1680. Atmosphere Furnaces
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

1681. Atmosphere Generators
12-page booklet on gas producers describes equipment and gives data on composition and applications of atmospheres. *Bellevue Industrial Furnace*

1682. Barrel Finishing
22-page book on single-unit installation to yield savings up to 95% in finishing various parts. *Almco Div.*

1683. Barrel Finishing
16-page manual on "Honite" finishing method for deburring and burnishing small metal parts. *Minn. Mining*

1684. Barrel Plating
Folder on barrel plating with unique contact arrangement for maximum current distribution. *Daniels*

1685. Barrel Plating
Bulletin PB108 on submerged barrel plating. *Hanson-Van Winkle-Munning*

1686. Bending
18-page brochure on bent and welded rings, flanges, angles, bands. Tables of areas of circles, decimal equivalents. *King Fifth Wheel*

1687. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

1688. Beryllium Copper
Helpful engineering information contained in monthly beryllium copper technical bulletins. *Beryllium Corp.*

1693. Brazing
24-page Bulletin 20 on advantages of Easy-Flo silver brazing alloy, with information about joint design and fast production methods. *Handy & Harman*

1694. Brazing
Bulletin 124 — on salt bath brazing process — shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies. *Ajax Electric*

1695. Brazing Applications
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

1696. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

1697. Bright Carburizing
Job data on bright carburizing and hardening gears. *Ipsen*

1698. Burners
Bulletin 123 on new series of burners for multi-purpose furnaces. *North American Mfg.*

1689. Aluminum

This recently published 152-page book★ presents general information of interest to users of aluminum sheet and plate. It is the only manufacturer's aluminum handbook devoted exclusively to this subject. Its content is presented in five sections dealing with the advantages of aluminum, commercial alloys of aluminum, fabrication, finishing and tabular matter.

Properties of 14 alloys are discussed individually, using tables and text to stress important features.

High points of all aluminum fabricating and working processes are summarized in a series of concise résumés emphasizing the advantages and disadvantages of each.

A blue-paper data section consists of 60 pages of tables relating to the use of sheet and plate. These include catalog and tolerance information, most mechanical and physical properties of all forms and tempers produced, some fabrication data, typical thermal treatments, weights, chemical resistance and miscellaneous data.

A definite conciseness was achieved in writing this book within the limits of 152 pages. Its orderly explanation of alloy symbol numbers and temper designations covers the salient factors briefly and clearly.

This is made to order for all who desire a quick outline of the most important aspects of this subject.

★Published by Kaiser Aluminum & Chemical Sales, Inc. Copies are available at no charge to readers of Metal Progress who circle No. 1689 on request card, page 32B.

1690. Bimetal Applications
32-page book on application of thermostatic bimetal. Property charts for 30 types. Design formulas. *W. M. Chace*

1691. Blast Cleaning
28-page Bulletin No. 100A on hose machines for hand-operated cleaning jobs. *Pangborn*

1692. Blast Cleaning
Bulletin No. 223 on blast cleaning barrels in sizes 3 to 18 cu. ft. *Pangborn*

1699. Burners
Bulletin on combination gas and oil burner. *Ra-Diant Products*

1700. Carbide Coatings
12-page Bulletin 8065, "Flame Plating", on method of applying tungsten carbide coatings. Comparative wear test data. Applications. *Linde*

1701. Carbide Segregation
Effect of carbide segregation in tool steel. *Latrobe Steel*

1702. Carbides
64-page catalog 52 gives latest information on carbide tooling. Completely illustrated details on all types of cutting tools. Handy tables for grade selection and cutting speeds. *Kennametal*

1703. Carbon Analysis
Folder describes method of rapid carbon determination. *Leitz*

1704. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Engineering*

1705. Carbonitriding
Job data on experiences in carbonitriding cylinders at Keller Tool Co. *Ipsen Industries*

1706. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs. time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

1707. Carburizing
16-page bulletin SC-134 reviews gas carburizing techniques and possibilities. *Surface Combustion*

1708. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

1709. Car-Type Furnaces
Heat treating large assemblies and castings at Yale & Towne described in Metal Minutes. *Sunbeam*

1710. Cast Iron
"Guide to the Selection of Engineering Cast Irons". *International Nickel*

1711. Centrifugal Castings
62-page book on centrifugally cast iron, steel, gray iron parts. ASTM specifications. *American Cast Iron Pipe*

1712. Chromium Stainless
Folder on uses of chromium stainless steels; table of analyses and properties. *Lebanon Steel Foundry*

1713. Cleaning
Story of automatic cleaning operations at Ford Engine Plant. *Metalwash Machinery Corp.*

1714. Cleaning
Story of equipment and process for cleaning of ball bearings at Fafnir. *Metalwash Machinery*

1715. Cleaning
Bulletin on equipment for cleaning and pickling of shell cases and other ordnance items. *Alvey-Ferguson*

1716. Cleaning
12-page Bulletin 68 deals with factors to consider in selecting metal cleaning equipment. *Despatch Oven*

1717. Cleaning Equipment
Folder on degreaser. Data on different models. *Topper Equipment*

1718. Cleaning Machines
12-page bulletin on washing and drying machines; conveyor, cabinet, drum and vertical types. *Industrial Systems*

1719. Cold Finished Steel
8-page bulletin on selection, use, relative cost of cold finished carbon steel bars. *Ryerson*

1720. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

1721. Compressors
12-page data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1722. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on A.C. or enclosed battery. *Illinois Testing Labs.*

1723. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

1724. Controls
16-page bulletin 18 on meters and controls for processing and other plants. *Bailey Meter Co.*

1725. Copper Alloys
124-page data book on wrought copper alloys. *Chase*

1726. Corrosion Prevention
Bulletin No. 730 on plastic paint for protection of metal surfaces exposed to acids, alkalis, oils, waters, alcohols. *U. S. Stoneware*

1727. Corrosion Resistance
35-page booklet on plastic materials of construction. *Atlas Mineral Products*

1728. Corrosion Resistance
32-page brochure on causes of corrosion and means of combating them. Choice of materials for condenser tubes. *Revere Copper & Brass*

1729. Cr-Mo Steel Tubing
Data Card 152 on 1½% Cr, 0.5% Mo steel tubing. Allowable working pressures. *Babcock & Wilcox*

1730. Crystal Models
Folder describes unique kit for constructing crystal models. *Harshaw*

1731. Cutting Fluids
"More Than a Coolant Is Needed" is new booklet describing cutting fluids and lubricants. *D. A. Stuart*

1732. Cutting Oil Chart
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

1733. Cutting Oil System
Data and charts on new cutting oil, dispensing jet and motor-driven pump. Test results of overhead flood with conventional coolants vs. jet. *Gulf Oil*

1734. Degreasing
24-page brochure on medium-pH cleaner to follow solvent degreasing or other precleaner. *Northwest Chemical*

1735. Densitometer
Bulletin 39 on densitometer comparator as an accessory for spectrographic analysis. *Baird*

1736. Drawing Compounds
Folder on lubricant for forming and drawing of stainless. *Hangsterfer*

1737. Ductile Iron Castings
12-page bulletin on pearlitic, ferritic and austenitic grades of ductile iron. Properties, 12 typical uses. *American Brake Shoe*

1738. Electrical Steel
80-page book of engineering data on silicon steels for the electrical industry. *Republic Steel*

1739. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1740. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

1741. Electrodes
8-page bulletin on recent developments in low hydrogen electrode field. *Alloy Rods*

1742. Electroforming
Folder on uses and advantage of electroforming. *Bone Engineering Corp.*

1743. Electron Microscope
New 20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

1744. Expanded Metal
28-page book on uses of expanded metal. Stainless steel, aluminum, Monel, Inconel, carbon steel. *Penn Metal*

1745. Fabrication Data File
Reference file of engineering information about equipment and processes used for stampings, heavy weldments and pressed steel shapes. *Brandt*

1746. Fasteners
40-page booklet on complete line of fasteners, their construction, uses, variations. *Simmons Fastener Corp.*

1747. Fasteners
32-page booklet on 28 fastener problems and how they were solved. *Elastic Stop Nut*

1748. Finishing
Brochure on cleaners, phosphating compounds, spray booth materials, paint stripping operations. *Pelron*

1749. Finishing
Six bulletins describing finishing compounds for stainless steel, aluminum, other metals. *Apothecaries Hall*

1750. Finishing
16-page bulletin on phosphatizing machine and other finishing equipment. *Cincinnati Cleaning & Finishing Mach.*

1751. Finishing
28-page catalog B-9 on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

1752. Flaw Detection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

1753. Flaw Detection
Reprint describes penetrant dye method for detecting fine surface defects. *Met-L-Chek Co.*

1754. Flaw Detection
12-page bulletin on location of flaws by two dye-penetrant inspection methods. *Turco Products*

1755. Flow Meters
37-page Bulletin 460-1 on differential-pressure-type flow meters. *Foxboro*

1756. Flow Meters
Bulletin on gas flow meter for furnace installations. *Hays Corp.*

1757. Flow Meters
24-page manual on application and installation of indicating flow meter. *Meriam Instrument*

1758. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1759. Fluxing Tubes
Folder S-6150 on graphite fluxing tubes used for degassing nonferrous metals. *National Carbon*

1760. Forgeability
112-page book, "Evaluating the Forgeability of Steels". Hot work characteristics in chart form for 94 steels. *Timken*

1761. Forging Manipulators
Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

1762. Forgings
20-page Catalog 51 on various types of forgings, their strength and related data. Tables, drawings. *Merrill Bros.*

1763. Forming
72-page Catalog B-4 on equipment for forming, bending, pressing. *Cincinnati Shaper*

1764. Foundry Alloys
24-page book on alloys for adding to ferrous and nonferrous melts. *Alter Co.*

1765. Foundry Coatings
Data on colloidal graphite for mold washes, pattern coatings, core coatings, chill coatings. *Acheson Colloids*

1766. Foundry Practice
Bulletin on unit for curing intricate cores by dielectric heat. *Allis-Chalmers*

1767. Foundry Supplies
Catalog 1043C on oil and gas-burning equipment for cupola lighting, mold drying, ladle heating, core baking, furnace heating. *Hauck*

1768. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1769. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

1770. Furnace Insulation
Bulletin on ceramic fiber that can give impressive savings compared with high-quality insulating brick. *Refractories Div., Carborundum Co.*

1771. Furnaces
High temperature furnaces for temperatures up to 2000 F. are described in leaflet. *Carl-Mayer Corp.*

1772. Furnaces
16-page bulletin on gas, electric and oil furnaces for heat treating and melting. *Knapp*

1773. Furnaces
Catalog and parts manual of kilns and electric furnaces. *L & L Mfg. Co.*

1774. Furnaces
16-page booklet "Proven Heat Treating Efficiency" displays complete line of furnaces. *Loftus Engineering*

1775. Furnaces
Bulletin 162 on high speed furnaces for forging, upsetting, extruding, stress relieving. *Surface Combustion*

1776. Furnaces, Annealing
Folder of performance and cost data on radiant tube and roller hearth furnaces. *Gas Machinery*

1777. Furnaces, Heat Treating
Catalog on furnaces for tool room and general-purpose heat treat. *Cooley*

1778. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1779. Furnaces, Heat Treating
Bulletin on furnaces for annealing, normalizing, hardening, tempering, forging. *Flinn & Dreffein Engineering*

1780. Galvanizing
4-page folder on recommendations for the proper preparation of materials prior to hot dip galvanizing. *American Hot Dip Galvanizers Assoc.*

1781. Gas Analysis
Folder on gas analysis equipment for thermal conductivity measurements. *Leeds & Northrup*

1782. Gas Carburizing
Bulletin on gas carburizing in rotary furnaces. *American Gas Furnace*

1783. Glass Seal Alloy
Data sheet on high-purity glass sealing alloy with 29% Ni, 17% Co, 53% Fe. *Vacuum Metals*

1784. Glass Seal Alloy
Bulletin on Rodar (29% Ni, 17% Co, 53% Fe) for sealing metal to hard glass. *Wilbur B. Driver*

1785. Gold Plating
Folder on salts for bright gold plating. Also lists equipment needed. *Sel-Rex*

1786. Graphite Electrodes
164-page vest-pocket data book on graphite electrodes and electric-arc furnace practice. *International Graphite*

1787. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1788. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

1789. Hardness Tester
Bulletin ET 439 on new portable hardness tester. *Newage International*

1790. Hardness Tester
Design and operating instructions for portable Vickers hardness tester. *Testing Equipment Co.*

1791. Heat Exchange
Bulletin 511 gives engineering data on heating and cooling applications of fintube equipment. *Brown Fintube*

1792. Heat Treating
56-page "Heat Treating Alloy Steels". *Republic Steel*

1793. Heat Treating
Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam*

1794. Heat Treating Aluminum
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1795. Heat Treating Baskets
Information on designs of baskets for heat treatment of small parts. *Hoffman*

1796. Heat Treating Fixtures
Folder shows 21 examples of heat treating fixtures, trays, baskets, retorts. *Allied Metal Specialties*

1797. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1798. Heat Treating Pots
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

1799. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

1800. Heavy Duty Cleaning
Booklet on LP cleaner for all metals except aluminum. *Cowles*

1801. High Speed Steel
8-page bulletin on M-2 type high speed steel. *Latrobe*

1802. High Speed Steels
Catalog of grades, applications, heat treatment of high speed steels. *Vanadium-Alloys Steel*

1803. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

1804. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

1805. High-Temperature Alloys
New 12-page booklet on fabrication and design data for stainless 330 (35% Ni - 15% Cr) and other alloys. *Rolled Alloys*

1806. High-Temperature Belts
24-page bulletin on metal conveyor belts. *Wickwire Spencer*

1807. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

1808. Identifying Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

1809. Illium
Data on corrosion resistance, strength and workability of Illium alloy. *Illium Corp.*

1810. Illium
Chart shows X-ray analysis curve for Illium. *North Am. Philips*

1811. Immersion Heater
Catalog on heater features application data for calculating power requirements for heat processing tanks. *Cleveland Process Co.*

1812. Impregnating Castings
Folder on 6-step impregnation process to eliminate porosity in castings. Includes data on impregnating material. *American Metaseal*

1813. Induction Heating
Book contains selector chart and heating and melting speeds for induction equipment. *Ajax Electrothermic*

1814. Induction Heating
12-page bulletin 5679 on induction hardening, brazing, annealing at 1000, 3000, and 10,000 cycles. *General Electric*

1815. Induction Heating
Bulletin 1440 on system for safety control of induction heating through use of components built into every unit. *Lindberg Engineering*

1816. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1817. Induction Heating
Data folder on megacycle tube-type machines for soldering, brazing, hardening. *Sherman Industrial Electronics*

1818. Induction Melting
Brochure on small, low-frequency induction melting furnaces for sand, permanent mold and die casting foundries. *Russ Electric Furnace*

1819. Industrial Finishing
Catalog A-653 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

1820. Industrial Planning
Booklet 127 on furnaces, ovens, dryers, and special automatic machines for industry. *Continental Industrial Engineers*

1821. Industrial Television
Folder on equipment and uses of television in industry. *RCA*

1822. Instruments
20-page Catalog 1053 on millivoltmeter-type instruments for indicating, electronic control and safety shut-off. *Minneapolis-Honeywell*

1823. Investment Castings
Production techniques, accuracy, advantage of investment casting, designing investment castings. *Arwood Precision Casting*

1824. Laboratory Equipment
"Laboratory Spotlight" catalogs laboratory ovens, colorimeters, balances, microscopes. *Harshaw*

1825. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

1826. Leaded Steels
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel*

1827. Leak Detection
Survey of custom leak detection service; equipment and procedure. *Consolidated Engineering Corp.*

1828. Leak Detector
Catalog of leak detectors, mass spectrometers, other instruments. *Consolidated Engineering*

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Shop records keep proving the logic of using **J&L "1200"** COLD FINISHED STEEL in terms of

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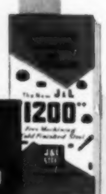

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1829. Low-Temperature Properties
Article on application of extreme low temperatures to metallurgy. Behavior of metals at low temperatures. *Arthur D. Little*

1830. Low-Temperature Tests
Bulletin MP9-1 on properties of 1020 steel at low temperatures and details of Collins helium cryostat. *A. D. Little*

1831. Machining Titanium
Recommendations for turning, milling, drilling, tapping and grinding titanium. *Mallory-Sharon*

1832. Magnesium Applications
60-page book gives 54 case studies on uses. *Dow Chemical*

1833. Magnesium Welding
Reprint describes an investigation to evaluate inert-gas-shielded metal-arc welding of magnesium. *Air Reduction*

1834. Magnets
Folder on lifting magnets gives sizes, lifting capacity and electric current necessary. *O. S. Walker*

1835. Marking Devices
20-page indexed catalog on marking devices and equipment. *Newark Stamp and Die Works*

1836. Material Handling
Bulletin 100 on plate lifting clamps. *Smith Material Handling Devices*

1837. Meehanite Castings
8-page bulletin on five engineering grades of Meehanite. Hardenability, other properties, uses. *Am. Brake Shoe*

1838. Melting
24-page book on electric furnaces for steel mills and foundries. Table of types, sizes, ratings. *American Bridge*

1839. Metal Cutting
64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

1840. Metallograph
Metallograph, described in catalog E-240, furnishes four different accurate images of same sample for complete identification with bright field, dark field or polarized light. *Bausch & Lomb*

1841. Metallograph
40-page brochure on Vickers research metallograph. *R. Y. Ferner*

1842. Metallurgical Apparatus
200-page catalog of metallurgical apparatus: cutters, grinders, mounting presses, polishers, metallographs, microscopes, cameras, testing machines, analytical apparatus, spectrographs, furnaces, accessories and supplies, and 250 recommended metallurgical books. *Buehler Ltd.*

1843. Metals Literature
Paper before Special Libraries Assoc. surveys various machine systems for literature searching. *A.S.M.*

1844. Micrographic Equipment
6-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000 ×. Full details on optics and accessories included. *Opplem Co.*

1845. Microhardness Tester
Bulletin DH-114 on Tukon hardness testers in research and industrial testing. *Wilson Mechanical Instrument*

1846. Microscopes
Catalog on Cooke microscopes includes data on incident light phase contrast equipment and illuminator. *R. Y. Ferner*

1847. Moly-Sulphide Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1848. Nonferrous Tubing
Bulletin on seamless, brazed and lock-

seam tubing in brass and copper. *H & H Tube and Mfg.*

1849. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1850. Paint Stripping
13-page instruction booklet on paint stripping from all metals. *Octagon Process*

1851. Peening
Bulletin on use of cut wire shot for peening and cleaning. *Park Chemical*

1852. Phase Contrast
16-page Bulletin D-104 on theory, applications and equipment for phase contrast microscopy. *Bausch & Lomb*

1853. Phosphate Coating
12-page "Phosphate Coating Chemicals and Processes" gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

1854. Pickling
80-page book "Efficient Pickling" covers all variables of process. Many charts and tables. *American Chemical Paint*

1855. Pickling
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g.*

1856. Piezoelectric Data
28-page technical discussion of piezoelectric elements and materials. Design and uses. *Brush Electronics*

1857. Piezotronics
20-page brochure on applications of piezoelectric materials. *Brush Electronics*

1858. Plating
Booklet on chemical plating process for applying nickel to difficult-to-plate parts and shapes. *Gen. Am. Transportation*

1859. Plating
Bulletin on metallic rectifier power supplies for electroplating. *G. E.*

1860. Porous Chromium
12-page bulletin on hard, porous chromium coating for cylinder bores and bearing surfaces. *Van der Horst*

1861. Powder Metallurgy
Data on annealed carbonyl iron powders, hydrogen reduced iron powders and Magna-tites. *Magnetic Powders*

1862. Powder Metallurgy
32-page handbook gives 24 case histories of parts designed or redesigned for powder metal production. Cost comparisons; definitions of terms and list of standards. *New Jersey Zinc*

1863. Powder Metallurgy
Reprint on high density iron powders, their structure and processing. *Plastic Metals Div.*

1864. Precision Casting
Discussion of alloy selection and design of investment castings. *Arwood Precision Casting*

1865. Precision Castings
8-page booklet on uses of precision castings, ferrous and nonferrous. *Jelrus*

1866. Precision Forgings
Data folder on small metal parts forged to within a few thousandths. *Utica Drop Forge*

1867. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

1868. Pyrometer Supplies
56-page Users' Manual and Buyers' Guide. Specifications, prices, thermocouple calibration data. *Bristol Co.*

1869. Pyrometer Supplies
Buyers' Guide for pyrometer supplies, No. 100-4. *Minneapolis-Honeywell*

1870. Pyrometers
Data on indicating pyrometers and dial-type thermometers for immersion use to 1500° F. *Seico*

1871. Pyrometers
Information on Xactemp pyrometers; also Xactline straight-line temperature control for use with any standard controller. *Claud S. Gordon Co.*

1872. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton*

1873. Quenching
8-page bulletin on continuous quench tank conveyor. *Klaas Machine & Mfg.*

1874. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

1875. Radiant Heat
Folder on flameless incandescent gas burner for drying, heating, heat treating. *Granco*

1876. Radiation Detectors
Specification Sheet 84 on Radiamatic compensated radiation detectors for use with variety of pyrometric instruments. *Minneapolis-Honeywell*

1877. Reamer Selector
Pocket-size selector lists 143 standard hole sizes which can be reamed. *Lavallee & Ide*

1878. Recorder Controllers
48-page ND 46(1) gives specifications, installation pictures of recorders and controllers for temperature, strain, other variables. *Leeds & Northrup*

1879. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000 F. *Johns-Manville*

1880. Refractories
Form 1409 on fused stabilized zirconia refractory for furnace linings, metal melting, other uses. *Norton Co.*

1881. Refractory Mixes
16-page bulletin 315 on properties and applications of sillimanite super-refractory ramming mixes and furnace patches. *Chas. Taylor Sons*

1882. Refractories
32-page data book on plastic refractory and its use in steel plant construction. *Ramtite*

1883. Resistance Testing
Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

1884. Riveting
64-page book covers selection, hole preparation, gun riveting, squeezer riveting and other methods, rivet removal and inspection. *Hi-Shear Rivet Tool Co.*

1885. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1886. Rubberized Abrasives
Folder on rubberized abrasives for burring, smoothing and polishing. *Cratex*

1887. Rust Preventives
12-page bulletin on water-soluble rust-preventive compounds. *Production Specialties*

1888. Rustproofing
Data sheet on slightly alkaline compound NR-31 for rustproofing iron and steel. *Enthone*

1889. Rust Removal
Booklet on rust and tarnish removal. Instructions on use of six new products. *Octagon Process, Inc.*

1890. Salt Bath Furnaces
Information on electrode-type salt bath furnaces. *Bellis*

1891. Salt Baths
75-page manual on salt baths for case hardening and heat treating. *DuPont*

1892. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1893. Screw Machine Products
64-page buyers' guide of companies available for contract work. Equipment available, secondary services and specialties. *N.S.M.P.A.*

1894. Screw Thread Inserts
Design Handbook 652 on screw thread bushings for all metals. *Heli-Coil*

1895. Selective Carburizer
Information on new product for use as stop-off during selective carburizing. *Walmil Co.*

1896. Shell Molding
4-page article in Metal Trends, Vol. 1, No. 1. *American Brake Shoe*

1897. Shell Molding
Folder on carbon equipment used in shell molding process. *Speer Carbon*

1898. Shot Peening
Selection and use of shot and grit for peening. *Cleveland Metal Abrasive*

1899. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

(*Continued on p. 32A*)

take a closer look at

Stainless STEEL PIPE SIZE Schedules

Don't be "penny wise and pound foolish" where stainless steel piping is concerned. The most economical choice does not always imply the least initial cost as working pressure, methods of joining, installation costs and allowance for loss by corrosion are critical factors. This is particularly true where costs resulting from failures in service—replacement of equipment and lost production due to down time—may exceed the initial cost of the piping.

Figure A

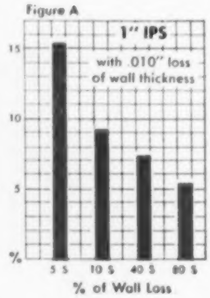


Figure B

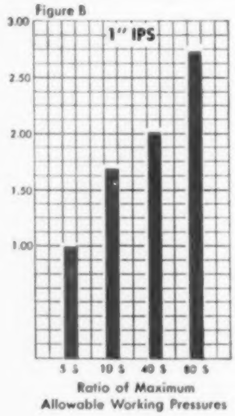


Figure C

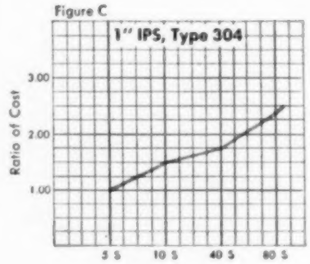
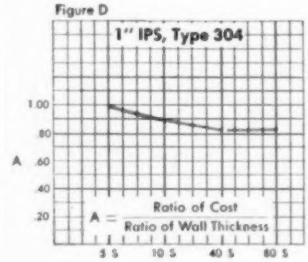


Figure D



CORROSION RESISTANCE

For long service life it is advisable to allow for some loss in wall thickness where stainless piping is employed to combat severe corrosion. As shown in Figure A even a small loss means an appreciable percentage loss of wall thickness in the lighter weight schedules.

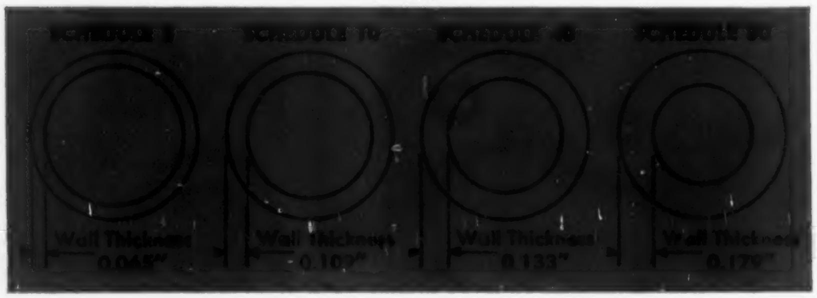
WORKING PRESSURES

As shown in Figure B, the heavier pipe schedules permit higher working pressures, thus perhaps permitting the use of smaller diameter piping, or offering greater flexibility for subsequent changes in operational procedures.

COSTS

Although the lighter schedules cost less, as shown in Figure C, you actually get more for your money with the heavier schedules because the ratio of increase in cost is *less* than the ratio of increase of wall thickness (Figure D).

1" IPS



While various types of fittings are available for the lighter weight pipe schedules, they should be examined carefully as to initial cost, installation cost, working pressure permitted and ease of adaptation to existing lines.

Whatever your stainless piping problems, Mr. Tubes—your B&W Tube representative—can provide valuable assistance. Consult him for advice on the stainless piping or tubing that will afford optimum cost-life ratio under your service conditions.

Methods of Joining & Installation Costs

From the standpoints of economy and ease of installation, it is extremely important that attention be given to methods of joining, fittings, etc. because:

1. Schedule 40 IPS is the lightest weight pipe specifically designed for threading.
2. Fittings which provide a good thread and also afford structural strength at the joint are not commercially available for lighter weight pipe.
3. Field welding of thin wall pipe is difficult.
4. Misalignment of connections can cause high installation costs.

TA 1709 (G)

B&W SEAMLESS and WELDED TUBES

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION

Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

(Continued from p. 31)

1900. Silicon Bronze
Article on silicon bronze from "Lavingot Technical Journal". *Lavin*

1901. Sodium
24-page book on handling sodium in the laboratory and plant. Application to descaling. *Ethyl Corp.*

1902. Solder
Leaflet on rosin core solder. Wire sizes, compositions and quantities. *Federated Metals*

1903. Solder Stripper
Data sheet on alkaline material for stripping tin, lead and lead-tin without attacking base metal. *Enthone*

1904. Soldering
Bulletin on solder preforms for various methods. *Kester*

1905. Soldering Irons
8-page bulletin on soldering irons and soldering iron tips. *General Electric*

1906. Soldering Irons
Folder on electric soldering irons, other soldering equipment. *Insulation & Wires, Inc.*

1907. Solution Heating
Bulletin 12 on electric heating of pickling and plating solutions. *Pyrosil*

1908. Sonic Thickness Tester
Measurement of wall thickness from one side by sonic method. *Branson*

1909. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

1910. Specifications Index
28-page cross index lists copper alloy specifications of nine different Government agencies. *American Brass*

1911. Specimen Grinders
6-page booklet describes grinders and surfacers for metallurgical samples, both belt and wheel types for wet or dry grinding. *Buehler Ltd.*

1912. Specimen Mount Press
Bulletin describes press featuring preheated premolds, rapid closing and universal application for thermosetting or thermoplastic materials in three sizes. *Buehler Ltd.*

1913. Spectrograph
16-page catalog G2-53 describes grating spectrographs for precision analysis. *Jarrell-Ash*

1914. Spring Steel
18-page reprint compares three alloy spring steels. *International Nickel Co.*

1915. Springs
12-page booklet on inspection and quality control of springs. *Hunter Spring Co.*

1916. Spring Steels
Spring steel catalog offers 785 sizes of hardened and tempered spring steels, and 133 cold-rolled and bright annealed sizes in stock. *Sandvik Steel*

1917. SR-4 Testing Machine
Bulletin 4202 on 50,000-lb. machine with weighing system based on SR-4 strain gage. *Baldwin-Lima-Hamilton*

1918. Stabilized Stainless
Bulletin 144 on Type 321 stainless tubing. Condensed data on properties and fabrication. *Babcock & Wilcox*

1919. Stainless Fabrication
133-page book covers welding, riveting, soldering, joint design, machining, forming, annealing, pickling, finishing of stainless steels. *U. S. Steel*

1920. Stainless Steel
12-page booklet on stainless alloy products for chemical and petroleum industries. *Solar Aircraft*

1921. Stainless Steel
Slide chart. Set top at a certain fabricating operation, bottom shows rating of each standard grade. On reverse side, heat treating and corrosion data are given. *Carpenter Steel*

1922. Stainless Steel
Bulletin gives examples of five types of stainless steel castings. *Sivyer*

1923. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fitting and specialty items. *Star Stainless Screw*

1924. Stainless Steel
44-page book gives detailed information on use of stainless steel in the chemical industries. *Crucible Steel*

1925. Stainless Steel
Bulletin shows plates, forgings, sheets, tank heads, flanges. *G. O. Carlson*

1926. Stainless Steel
32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. *International Nickel*

1927. Stainless Steels
20-page book on uses of stainless steels. *Electro Metallurgical*

1928. Stainless Tubing
28-page book on corrosion, uses and fabrication of stainless steel tubing. *Steel and Tubes Div., Republic*

1929. Steel Tubing
May issue of Tube Bulletin
article on improvement of qu
tubular products. Also detaile
list. *A. B. Murray*

1930. Steel Tubing
48-page Handbook F-3 on fab
and forging steel tubing. I
shaping, cutting and joining op
described. *Ohio Seamless Tube*

1931. Stress Relieving
Bulletin 650 on car-bottom,
tion-type furnace for stress r
Mahr Mfg.

1932. Subzero Freezer
8-page folder on portable
110-volt a.c., operating to −180
shrink fitting, hardening, st
and testing. *Webber Appliance*

1933. Subzero Treatmen
12-page bulletin on subzero tr
of tool steel and increase in
resulting. *Sub-Zero Products*

1934. Superalloy Fasten
"Bolt News" article tells h
superalloys are being made int
ers for jet engines, guided mis
atomic propulsion applications
Harper

1935. Super High Speed
Folder on molybdenum, 8%
high speed steel for use at spe
25% greater than with ordina
speed steel. Heat treatments,
tive coatings and uses. *Firth*

1936. Surface Pyrometer
Bulletin 168 on instrument f
accurate readings of surface t
tures. *Pyrometer Instrument*

1937. Surface Roughnes
8-page bulletin on basic feat
applications of direct reading s
filometer. *Micrometrical Mfg.*

1938. Temperature Con
Bulletin F 5783 on Model 2
Capacitrols. *Wheelco*

1939. Temperature Con
Catalog of pyrometer suppl
data on thermocouples, protecti
other accessories. *Arklay S.*

1940. Temperature Con
Data sheets on high resista
cating pyrometers. Also con
resistance thermometers. *W*

1941. Temperature Con
Bulletin 50H describes ther
pyrometer controller. *Therm*

1942. Tempering
Bulletin 1E 11 on tempering
applications in liquid baths. *I*

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1943. Test Chambers
Catalog folder on environmental test chambers for temperature, humidity, altitude and various combinations including extremely low temperature. *American Research Corp.*

1944. Test Chambers
Bulletin on test chambers for temperatures from -100 to +200° F., humidity from 20 to 90%, pressures corresponding to 0 to 80,000 ft. altitude. *Tenny Eng'g.*

1945. Testing
Bulletin on mechanical and nondestructive testing and on certification in accordance with procedure set up by the American Standards Association. *American Standards Testing Bureau*

1946. Testing Equipment
New 80-page illustrated catalog lists over 130 testing and measuring equipments for laboratory and production-line use. *General Electric*

1947. Testing Machines
28-page catalog on screw power universal testing machines and accessories. Construction, specifications. *Riehle*

1948. Testing Machines
Brochure on machines for testing hardness, compression, tensile properties. *Steel City Testing Machines*

1949. Testing Springs
Bulletin on two high-power spring-testing machines. *Testing Equipment*

1950. Testing Tubing
Bulletin on test stand for determining physical characteristics of tubing up to 3 in. dia. *Dommers Co.*

1951. Thermocouple Data
42-page Bulletin TC-9 on thermocouples, radiation detectors, resistance bulbs, accessories. *Wheelco*

1952. Thermocouple Sheath
Bulletin 6169 on graphite thermocouple sheath parts. *National Carbon*

1953. Thermocouples
36-page Bulletin 235-4 describes various types of thermocouples, extension wire and other accessories. *Foxboro*

1954. Thermocouples
44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. Tabular data on accuracy and limits of couples. *Leeds & Northrup*

1955. Thread Inserts
Bulletin 661 on wire thread inserts. *Heli-Coil*

1956. Tin
Monthly newsletter, "Tin News", gives information about prices, supply, demand. *Malayan Tin Bureau*

1957. Titanium
30-page data book on properties of commercially pure and alloy titanium, melting, forging and rolling. 16 charts and micros; 4 hardness conversion curves for titanium. *Republic Steel*

1958. Tool Steel
20-page booklet on selection of proper tool steel support material for use with carbide tools. *Allegheny Ludlum*

1959. Tool Steel Color Guide
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

1960. Tool Steel Heat Treat
Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

1961. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

1962. Tubing
Mechanical and working characteristics, heat treating behavior and weldability of 9% nickel steel tubing. *International Nickel Co.*

1963. Tubing Failures
Factors affecting tube life in high-pressure, high-temperature applications are presented in 40-page booklet, the result of a great number of investigations of failures. *Babcock & Wilcox*

1964. Tumbling Barrels
10-page catalog B-8 gives specifications, applications of six types of tumbling barrels. *Globe Stamping Div.*

1965. Tungsten Electrodes
Wall chart gives data for inert-gas arc-welding of aluminum, magnesium, stainless steel with pure and thoriated tungsten electrodes. *Sylvania*

1966. Uranium
36-page book on uranium industry of the Colorado Plateau. *U. S. Vanadium*

1967. Vacuum Finishing
Use of vacuum metallizing in manufacture of plastic and metal parts. *National Research Corp.*

1968. Vacuum Metallizing
Reprint "High Vacuum Metallizing of Metals and Plastics". *Consolidated Vacuum Corp.*

1969. Vacuum Metallizing
Bulletin on equipment for industrial vacuum metallizing. *Optical Film Eng'g.*

1970. Vacuum Pumps
24-page Bulletin V51 on high-vacuum pumps and accessories. *Kinney Mfg.*

1971. Valves
50-page booklet on valves for the process industries. *Gas Machinery*

1972. Weld Positioners
Bulletin R-228A on turning rolls for positioning cylindrical forms for welding. *Worthington Corp.*

1973. Weld-Rod Dehydrating
Bulletin on low-hydrogen electrode stabilizer. Specifications of equipment for dehydrating mineral shielding on low-hydrogen electrodes. *Archer*

1974. Welding Electrodes
Bulletin on electrode selection for welding stainless and alloy steels. *Arcos*

1975. Welding Electrodes
Application chart for stainless, alloy and nonferrous electrodes. *Weldwire*

1976. Welding Rods
6-page bulletin on bronze welding rods. Table gives ASTM, AWS and Government specifications. *Titan Metal*

1977. Welding Stainless
12-page bulletin on arc welding electrodes for stainless steel. *Metal & Thermit*

1978. Welding Torches
Booklet on Heliarc torches for inert gas shielded arc welding. Also data on electrode selection, nozzles and argon cylinders. *Linde Air Products*

1979. Wire Baskets
84-page book on fabricated baskets for dipping and heat treating. *Cambridge Wire Cloth*

1980. X-Ray Chart
Wall chart shows characteristic secondary X-ray beams for elements from sodium to uranium. *N. Am. Philips*

1981. X-Ray Diffraction
Analytical applications of X-ray diffraction using direct measurement techniques. *X-Ray Dept., Gen. Electric*

1982. X-Ray Supplies
50-page catalog of industrial X-ray supplies and accessories. *Westinghouse*

June, 1953

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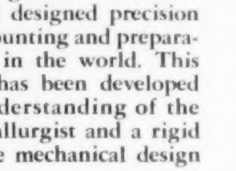

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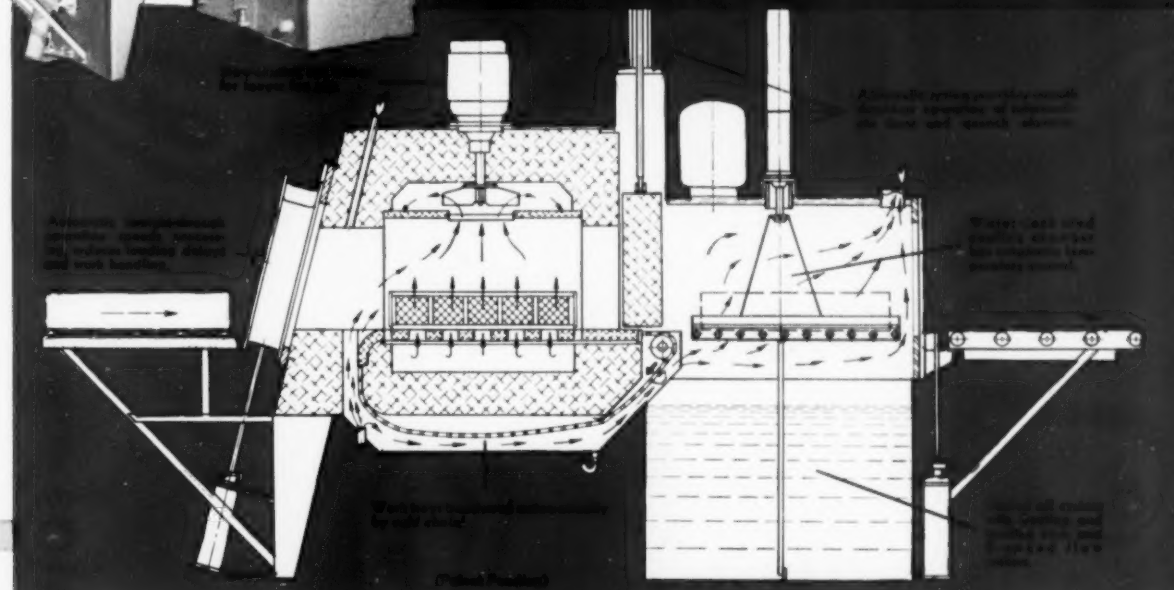

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4 Quench timer
5 Hi oil flow timer
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7 Cycle start button

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Stress Relieving	Carburizing and Hardening
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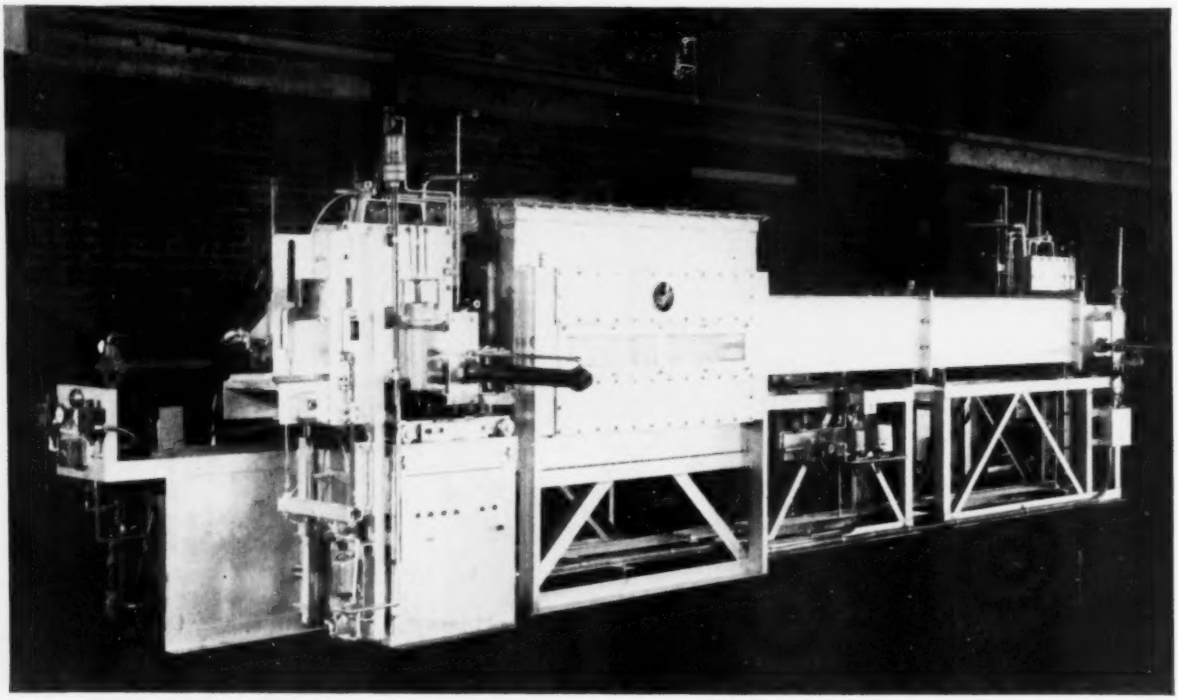

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3 SIMPLICITY
of furnace construction

4 LESS DOWNTIME
...no need to cool or unload during replacement.

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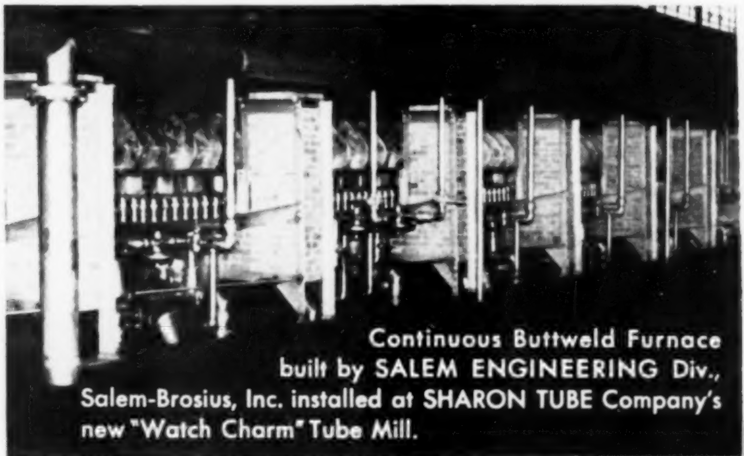

Continuous Buttweld Furnace built by SALEM ENGINEERING Div., Salem-Brosius, Inc. installed at SHARON TUBE Company's new "Watch Charm" Tube Mill.

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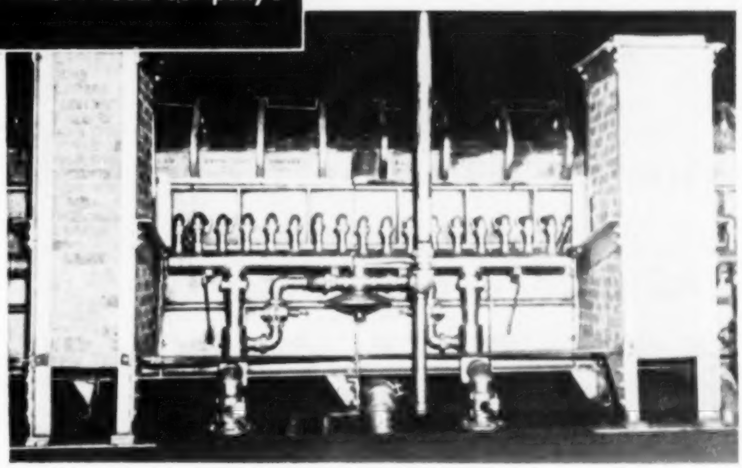
ft of pipe per minute

187
lb/hr per sq ft of hearth



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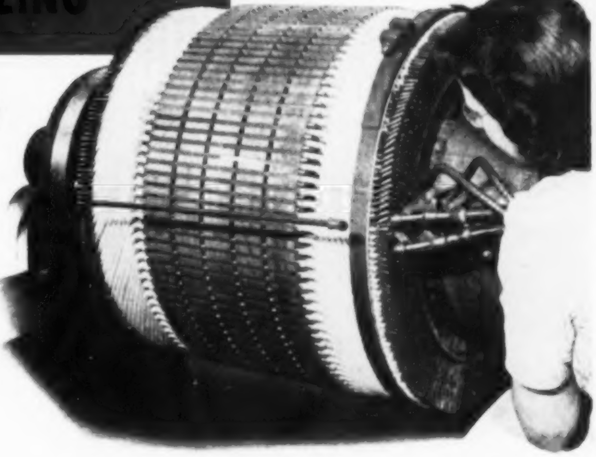

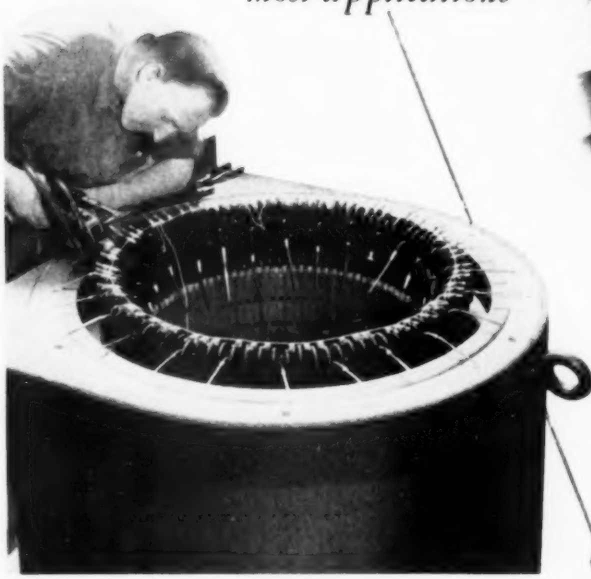

Commutator risers are silver alloy brazed to armature coils and cross connectors. For lap joints ELLIOTT uses the incandescent carbon tong-type of heating.

Connecting coils within phase groups of an A.C. machine by silver alloy brazing.

"Experience and test have proven that silver alloy brazing produces far superior joints" says the ELLIOTT COMPANY one of the country's principal manufacturers of motors and generators and other power equipment.

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The alloys primarily used by Elliott are the low-temperature silver brazing alloys EASY-FLO and SIL-FOS—strong evidence that they best satisfy the metal joining requirements of electrical equipment.

What ELLIOTT says about *EASY-FLO* and *SIL-FOS* joints

... They're extremely strong — in all cases, higher than the yield strength of the copper.

... They're ductile, enabling them to withstand the stresses and strains of shock loading, vibration and temperatures equally as well as the copper itself.

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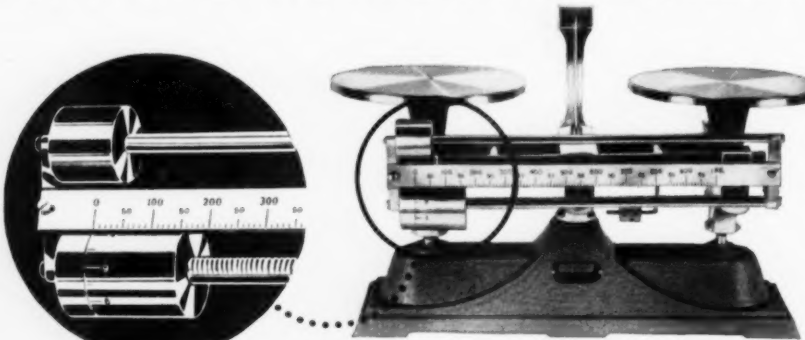
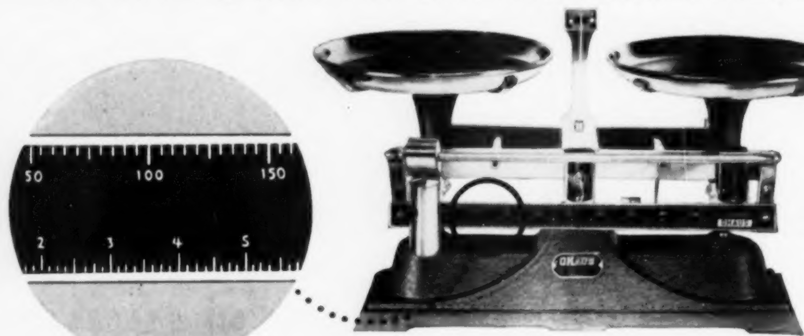


The Micrometer Poise . . . makes it possible to weigh a complete range from 0.5 gram to 1000 grams without the use of loose weights. Poise is moved along the beam for rapid traverse, rotated for final positioning.



Single Beam with Dual Calibrations . . . both metric and avoirdupois standards make the balances extremely versatile. All models have a capacity of 5 kilograms and a sensitivity of 0.5 gram.

H-2845 Balance with Micrometer Poise. Capacity 5 kg, sensitivity 0.5 gram; beam calibrated 1000 x 0.5 gram. Furnished with 7" diameter satin finish stainless steel plates. Equipped with tare beam and poise of 1 pound capacity **\$90.00**

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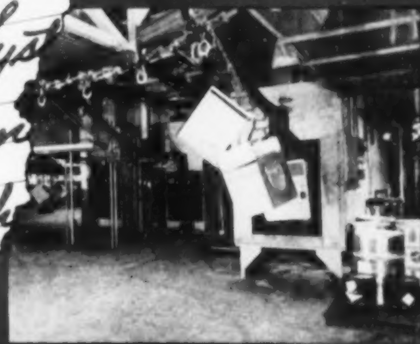
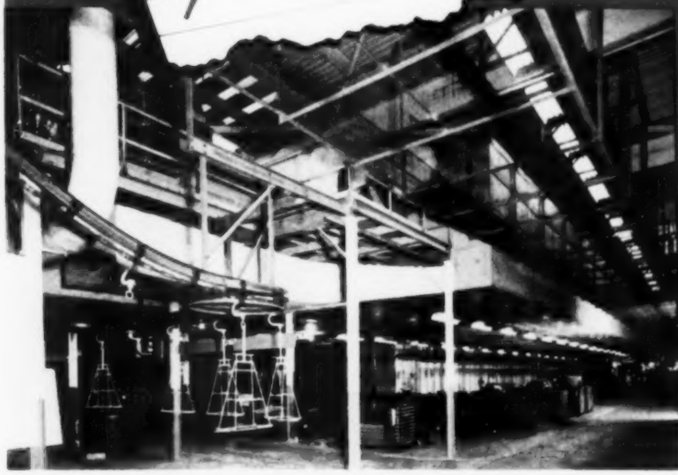
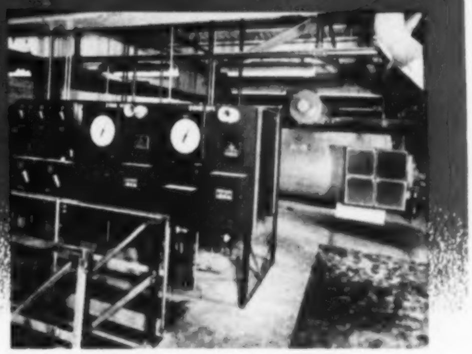


A DESPATCH continuous conveyor Multiple-stage Washer in operation. The view shows the entrance end.



A partial view of DESPATCH continuous conveyor Finish Bake Ovens on a large refrigerator finishing line.



Part of the heating equipment and control panels for the DESPATCH Finish Bake Ovens shown in the picture at left.

Why You Should Select **DESPATCH** For Your **FINISHING EQUIPMENT**

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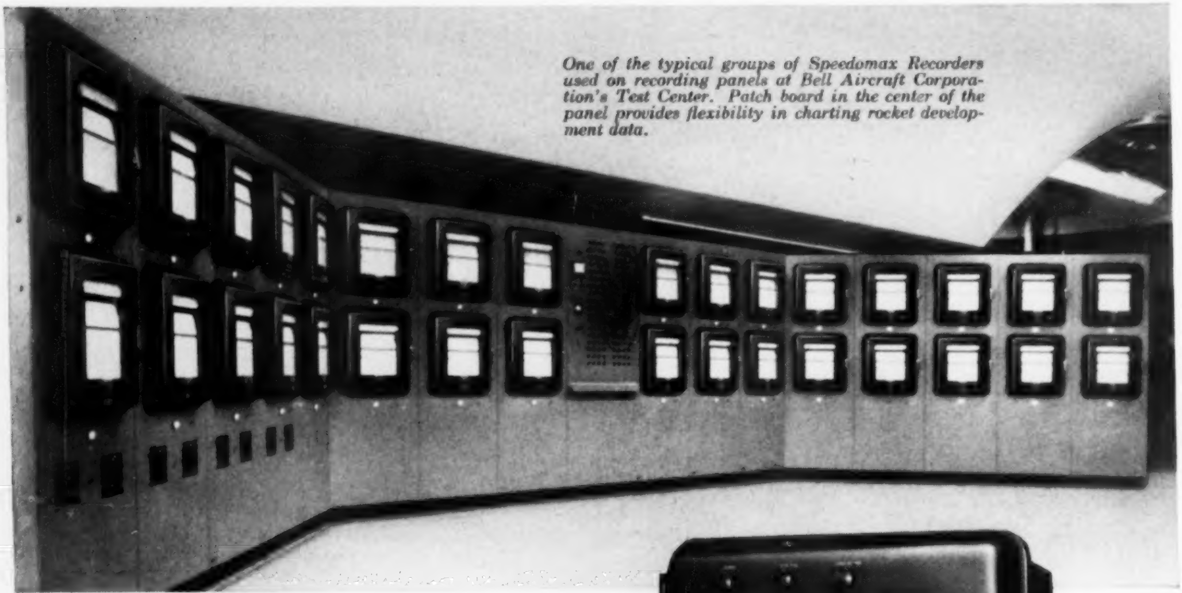

One of the typical groups of Speedomax Recorders used on recording panels at Bell Aircraft Corporation's Test Center. Patch board in the center of the panel provides flexibility in charting rocket development data.

Just set the knobs at top of instrument for the desired range and zero, and this AZAR recorder is adjusted to your exact specs . . . spreads any millivolt value from one to twenty across the full chart width, for measuring Force, Weight, Temperature, Speed, Voltage or any condition which yields an electrical recorder signal.

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A general description of this instrument is available, and will be especially useful if you can describe to us the nature of your recording problem. Contact our nearest office or write 4927 Stenton Ave., Philadelphia 44, Penna.

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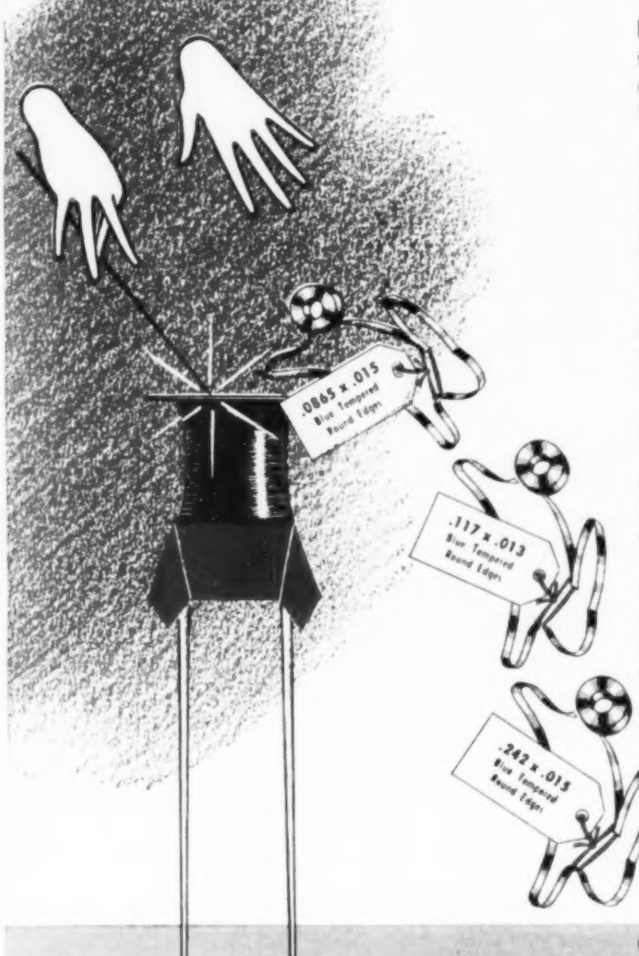

Naturally, Sandvik's stock of over 780 spring steel sizes includes many odd ones. The exact size and quality you want may be among them. Why not check with Sandvik?

In fact it makes sense to check with SANDVIK regardless of whether your size requirements are extraordinary or not. If spring steel *performance* is important to you, there's a good chance you'll find a SANDVIK steel that will suit you to a "T."

SANDVIK cold rolled, high carbon strip steel is available:

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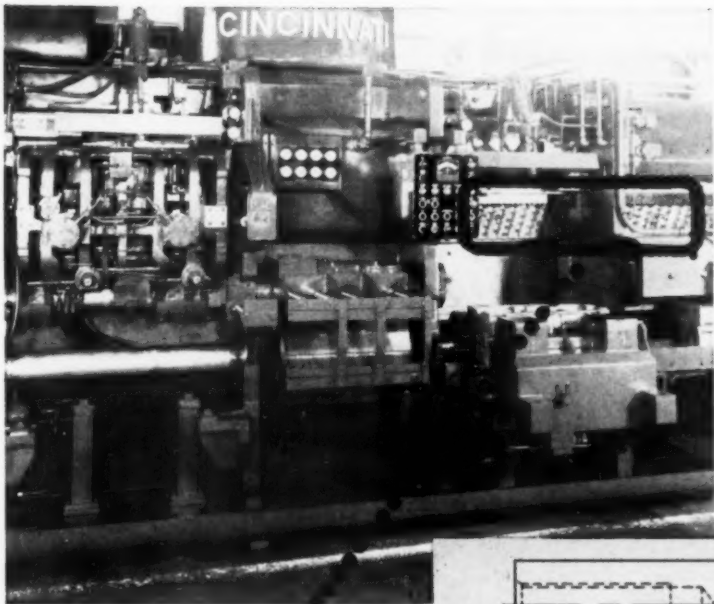

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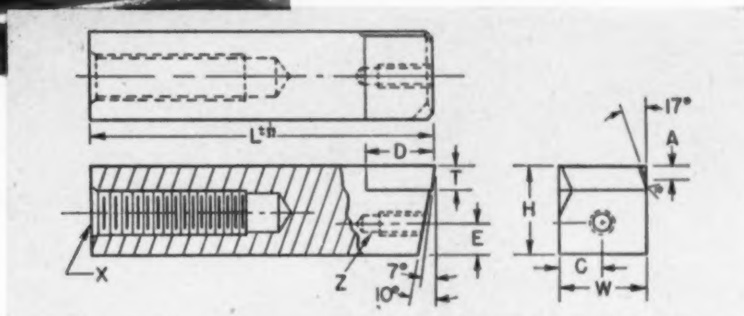
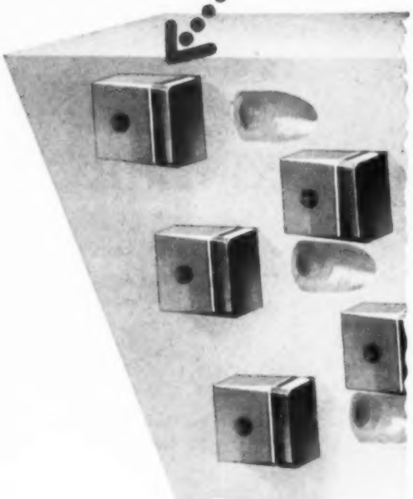
Firthite tipped Broach Tools for Off-the-shelf delivery!



LEFT HAND	RIGHT HAND	W	H	L	T	D	A	C	E	X	Z
CBL-10	CBR-10	.610 .613	.613 .611	2 1/4	5/32	3/8	5/64	0	0	1/4-20 N. C.	NONE
CBL-12	CBR-12	.735 .739	.737 .739	3	3/16	3/4	5/64	0	0	3/8-24 N. F.	NONE
CBL-16	CBR-16	.988 .983	.988 .986	3 13/16	1/4	3/4	5/32	.500 .490	3/8	1/2-20 N. F.	1/4-20 N.C.

3 Standard Sizes Available for High Production Broaches



FIRTHITE standard broach tools are carefully manufactured with special alloy steel shanks, drilled and tapped as shown in the dimensional drawing.

Firth Sterling, always a leader in machine tooling progress, now offers *standard* broach tools for *off-the-shelf delivery* in the sizes and styles shown above.

This new addition to the constantly expanding line of standard Firthite Carbide Tools is the result of close cooperation with the builder of the huge new broaching machines used to machine the cylinder blocks of today's mass-produced automobile engines.

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R-270

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Metal Progress . . . . June 1953 Vol. 63, No. 6

Engineering Articles

Critical Points

Correspondence

Digests of Important Articles

Departments

Atomic Power no Chimera

To a meeting of the U. S. Atomic Energy Commission's Advisory Committee on Technological Information, held at Brookhaven National Laboratory (away out on Long Island at a place known to World War I doughboys as Yaphank and to World War II G.I.'s as Camp Upton), and became more and more convinced from what I saw and heard there that the production of large blocks of central station power from atomic reactors is much closer than ordinarily supposed. This is a fair conclusion from the fact that four teams of engineers and executives representing large power companies and associated industries in the Detroit, Chicago, St. Louis and San Francisco regions have studied independently the A.E.C.'s reactors and scientific data for a year, and each comes up with a recommendation that his firm should appropriate anywhere from 40 to 80 million of its own dollars and get going immediately. Even more significant is the circumstance that each group recommends a different type of reactor! (There are 30 or 40 alternatives arising from the use of fast, slow or intermediate neutrons; natural or enriched uranium or thorium fuel, solid or fluid; carbon or heavy water moderator in homogeneous or heterogeneous system; water, gas or liquid metal or salt for heat transfer medium.) Most of these recommendations for prompt action are contingent upon the assumption that the Atomic Energy Commission will buy the plutonium byproduct.

If a central power plant were based on the conventional uranium-graphite pile the power company could doubtless avoid lots of trouble by getting the fuel rods of natural or enriched uranium from the Atomic Energy Commission and returning the fuel to the Commission at the end of its economic life for separating the plutonium and the fission products. However, one of the commercial groups (Dow Chemical and Detroit Edison) favors the fascinating idea that the uranium fuel be dissolved or dispersed as fine particles in molten metal, and that this be circulated continuously through a self-contained refinery which extracts the plutonium and fission products. Many of the engineering, chemical and metallurgical aspects of such systems have been studied in the Nuclear Engineering Laboratories at Brookhaven. They are difficult, but only a confirmed pessimist would pronounce them insoluble.

Critical Points

by the Editor

When all this is added to the results of intensive work being done by governmental agencies on nuclear engines for aircraft, for submarines and aircraft carriers, and on "package power plants" for isolated army installations, it looks as if usable power from the atom is in the relatively near future, at least for places where conventional fuels are expensive or too bulky or heavy to handle. Likewise, the chances of large central power plants, fueled with uranium rather than coal, oil or gas, are improving rapidly. In this last category, economics looms as large as engineering, and of course the dollar balance will eventually rule the participation of private enterprise.

Cooperation of A.E.C. With Industry

The equipment and facilities at Brookhaven National Laboratory are owned by the Atomic Energy Commission, and the Laboratory is operated under contract by Associated Universities, Inc., a group of nine universities in the northeastern region. Gerald F. Tape, deputy director, said that the scientific staff now contains 255 men of professional status, augmented by about 20 "paid visitors", mostly university science teachers on extended leave. Since the primary objective at Brookhaven is to study the constitution of the atom, and since fundamental scientific information on all chemical elements no heavier than lead is not held secret, Dr. Tape estimated that 80% of the work is on unclassified (public) projects and 20% on classified (secret) projects. Hence the presence of an additional 40 full-time or part-time "guest scientists" who use the extraordinarily fine equipment for investigations near to their heart and whose salaries are paid by other educational or industrial organizations. When asked how a progressive firm in the metals industries could participate in this program, he said that the proper executive and the prospective guest scientist should confer with his staff and decide whether a project could be undertaken which would be valuable both to Brookhaven's basic program and to the indus-

trial organization. (Another place to originate two-way exchange between industry and the Atomic Energy Commission is the Office of Industrial Development, A.E.C., Washington, headed by William L. Davidson.) Any immediate advantage to such an industry from co-operative work at Brookhaven could not be guaranteed, other than to gain some familiarity with radioactive metals and with special metallurgical research equipment for most extreme conditions. As an example of this work, David Gurinsky ⊕, chief metallurgist of the Brookhaven Laboratory, is supervising an extended program of studies into various unusual alloy systems, and on corrosion (alloying) of containers by liquid metals. Unique equipment exists for such things as polishing, etching and micrographing dangerously radioactive alloys by remote control, for measuring creep of metals at high temperatures while being bombarded with neutrons in the center of a reactor, and for automatic welding of tubing of highly reactive metals in a completely enclosed space, either under protective atmosphere or no atmosphere at all.

How to Make a Welding Machine for $500

With other members of the Cleveland Section of the American Welding Society, toured the new plant of Lincoln Electric Co. – a true product of American ingenuity and free enterprise, and a handsome monument not only to the advanced ideas incorporated in the design and manufacture of welding equipment, but also to the unconventional employee relationship and incentive plans. Access to this windowless factory is by a somewhat detached marquee housing handsome stairways down to a broad underground passageway leading to the various departments. Cafeteria, all locker and wash rooms, and the welding school are on this lower level. Executive offices are above, at the very center; they are surrounded by operating offices which in turn open directly to the manufacturing floor.

The welding school deserves more than mere mention, for one cannot help feeling that the commercial success of Lincoln Electric Co. is in no small part due to its insistence that superior welding equipment must be supplemented by sound design and good workmanship. The school has 67 completely equipped welding benches; the course takes four weeks; the tuition is $25. (The classes are usually full; during the war the school ran continuously, four shifts a day!)

The building is a long rectangle; mid-length is the office area; in one end electrodes and welding flux are manufactured; the other end is devoted to welding machines. Railroad tracks and truck docks run lengthwise of the entire building – for receiving raw material on one side; for shipping the finished product on the other. Flow in process is essentially unidirectional. For example, complete welder armatures are made in one bay; end brackets in the adjoining one; these major subassemblies are the only things which move at right angles to the main flow.

Two-ton bridge cranes (floor operated) span each bay; others run lengthwise over receiving and shipping docks. The cranes serving the receiving dock have girders spaced far apart so the bay cranes can be run into them like a long-span trolley and so be moved from bay to bay. Thus all raw material is transported in slings, boxes or on skids by overhead crane – hand or power trucks are conspicuously absent. Assembly is on appropriate slow-moving conveyers.

Manufacture is in five basic designs in a minimum of output ratings; other variants have to do principally with mountings. This simplifies greatly the flow of parts, and reduces the number of machine tools and assembly lines. Consequently the factory looks like a huge warehouse with material at the point of use. Modern machinery is scattered here and there, each all but hidden behind stacks of parts coming to it or awaiting further work at the next station. This observer commented that this arrangement seemed to represent an excessive investment in slow-moving material in process, but received the impression from his guide (Bill Stewart, sales manager of the Cleveland District) that inventories may seem to be large because they are accumulated in one central place rather than scattered in isolated departments or even in suppliers' factories. At the present time, all inventories tend to be large as a necessary hedge against sporadic deliveries of raw materials. Furthermore, one might guess that the economical size of the stocks of materials in process has a close relationship to the volume of daily production; it would *appear* to be much less in a plant making three thousand units per day than one completing three hundred.

"Color" and Reflectance of Stainless Steels

NUMBERLESS USES of stainless steels depend on their ability to resist tarnishing or staining and to polish readily to a bright and lustrous surface. Eye appeal is often one of the principal reasons for selecting these alloys, yet there appears to be little information on the physical characteristics which determine the appearance of a polished surface – their light-reflecting characteristics and what is called "color".

Even casual observation shows that there are differences in appearance between identically polished surfaces of stainless steel of various kinds and of other metals such as silver, aluminum, and nickel. The physicist would say that these differences are clearly the result of inherent dissimilarity in the light-reflecting properties. A familiar example is the contrast in "color" of the silver handle and the stainless steel blade of a modern table knife. More subtle variations exist between chromium-plated and stainless steel articles. This has been commented on from time to time in the literature, but opinion appears to be far from unanimous on the actual nature of the colors.

Within the same family of alloys, faint differences in appearance are generally recognized between the plain chromium steels and the chromium-nickel stainless steels. There also is reason to suspect that finishing or polishing operations can affect color. It is common practice, for instance, to refer to certain buffing operations as "color buffing" although no clear-cut statement has been found of the exact effect of this operation on the reflectance properties of metals – if, indeed, any.

With the growing use of stainless steels in ornamental applications, it should be of value to establish the origin and nature of these differences. Specifically, an attempt was made by our laboratories to determine by actual physical measurement the reasons why stainless steels are different in appearance from some of the other common metals, to what extent variations in composition affect their reflectance properties, and to examine the effects of different polishing methods.

Physical Considerations – When light is reflected from a surface it may be altered in two principal ways: First, the spatial or geometrical distribution of the light rays may be changed – that is to say, a beam of parallel

By F. K. BLOOM, Research Metallurgist
Armco Steel Corp., Baltimore, Md.

Three Factors Describe "Color"

rays striking a rough or matte surface is reflected as rays scattered randomly in all directions. Second, the spectral composition of the incident light and its intensity may be altered; white light falling on a polished copper surface, for instance, is altered spectrally because the portion of the light containing short wave lengths at the blue end of the spectrum is reflected very poorly or largely absorbed by the copper, whereas the long wave lengths at the red end of the spectrum are reflected almost perfectly. As a result, the reflected light contains a much higher percentage of red wave lengths than were originally present. This is the physical statement of the common fact that copper appears red in daylight. The total intensity of the light is also diminished because of this variable and incomplete reflection.

The first-mentioned effect – spatial distribution of the light – is a function of the surface texture and is independent of the composition of the metal. The second effect – spectral distribution of the light – is largely independent of the surface texture and depends on the material itself. "Color", in technical parlance when referring to metal, usually means an ill-defined combination of results of the two effects. (Henceforth it will not be printed in quotation marks, even though it will be used in this limited but more exact sense.) At any rate, our investigation was based on a physical comparison of the color of different metals or the effect of finishing methods by establishing the amount of reflection at various wave lengths in the visible spectrum. Physicists call such data "spectral reflection factors".

Polished samples of a variety of grades and finishes of stainless steels were submitted to the Electrical Testing Laboratories in New York, where autographic charts showing per cent reflection at various wave lengths were obtained on a Hardy recording spectrophotometer. Figure 1 shows typical curves.

Reflection curves by themselves define the light-reflecting characteristics of the metal. But alone they are not sufficient to describe the color which the surface possesses, because this also depends on the color of the light under which it is viewed and the characteristics of the viewer's eye. Normal eyes are not equally sensitive to all parts of the spectrum. These factors were accounted for by using established values for the energy distribution of a standard illuminant equivalent to average sunlight, and standard "tri-stimulus sensitivity factors" for people of normal color vision. The reflection curves can thereby be translated into three quantities or factors, which then "describe" the color.*

The first of these factors is called "dominant wave length". It describes the primary quality of a color surface which is its hue; that is, whether the color is red, yellow, green, etc. In Table I it is noted that the dominant wave length of all the stainless steels examined is 575 millimicrons. This lies in the yellow portion of the spectrum. The hue of stainless steels, then, is a yellow-tan shade which matches this particular wave length. As another example, copper has a dominant wave length of 585 millimicrons, which lies in the red-orange portion of the spectrum.

The second quantity needed to define a color is its strength or "purity"; that is, whether the color is weak or vivid. Purity is expressed as a percentage value and is related to the

*For those who are interested, an excellent description of the method used in calculating these quantities will be found in A. C. Hardy's "Handbook of Colorimetry" (Technology Press, Massachusetts Institute of Technology, 1936).

Fig. 1 – Reflectance of Common Metals as Measured at Various Wave Lengths. Samples of the stainless steels were examined after receiving a polish suitable for metallographic examination (not etched)

amount of pure monochromatic light of the dominant wave length which, when mixed with white light, will result in a color matching that of the sample. From Table I it will be seen that the majority of metals examined are very low in purity; the colors are very weak. Experience with these samples suggested that when the purity was as low as 2%, as it is for the plain chromium stainless steels even when viewed under the ideal lighting of a color-matching cabinet, most people were

unable to detect the presence of color with certainty. At 4% purity most eyes could just detect color, while at higher levels color was generally observed without difficulty.

The third and last quantity required to define color is its brightness or "reflectance". This determines whether a color is light and brilliant or dark and gray. It is related to the percentage of the total amount of visible light

Table I – Color and Reflectance of Various Metals

Material and Finish	Composition			Color Factors *(a)*			Color Description
	Cr	Ni	Other	Dominant Wavelength	Purity	Reflectance	
Type 410 *(b)*	12.4	–	C 0.11	575 μμ	2%	61.7%	No noticeable hue, very slightly grayish
Type 420 *(b)*	13.1	–	C 0.40	575	2	61.7	No noticeable hue, very slightly grayish
Type 430 *(b)*	16.9	–	C 0.10	575	2	62.6	No noticeable hue, very slightly grayish
Type 430 *(c)*	–	–	–	575	5	51.0	Very faint yellowish-white, more gray than above
Type 431 *(b)*	16.4	1.6	C 0.12	575	2	62.7	No noticeable hue, very slightly grayish
Type 446 *(b)*	25.9	–	C 0.12	575	2	64.0	No noticeable hue, very slightly grayish
Type 304 *(b)*	18.5	9.0	C 0.04	575	4	67.4	Extremely faint, very slightly grayish, yellowish-white
Type 304 *(d)*	–	–	–	575	6	54.9	Very faint yellowish-white, more gray than above
Type 304 *(c)*	–	–	–	575	5	60.9	Very faint yellowish-white, more gray than above
Type 304 *(e)*	–	–	–	575	4	67.2	Same as metallographic polish
Type 316 *(b)*	17.6	12.5	Mo 2.77	575	4	67.6	Same as Type 304 *(b)*
Type 309 *(b)*	24.3	12.8	C 0.07	575	4	67.7	Same as Type 304 *(b)*
Type 310 *(b)*	26.9	21.5	C 0.10	575	4	67.3	Same as Type 304 *(b)*
18-8 Cr-Cu *(b)*	17.8	–	Cu 8.0	575	2	61.6	Same as Type 410 (12% Cr)
18-21 Cr-Co *(b)*	18.3	–	Co 21.0	575	4	68.0	Same as Type 304 (18-8)
18-20 Cr-Mn *(b)*	18.2	–	Mn 18.6	575	4	67.8	Same as Type 304 (18-8)
"Boneusil" *(b)*	10.0	–	Mn 29.2 Cu 3.2	575	4	66.0	Same as Type 304 (18-8)
Armco ingot iron *(b)*	–	–	C 0.02	575	2	59.0	No noticeable hue, grayish
Silver plate *(f)*	Commercial			575	4	94.9	Very faint, very bright yellowish-white
Sterling silver *(f)*	Commercial			575	6	93.9	Faint, very bright yellowish-white
Nickel-silver *(b)*	Ni 20, Cu 55, Zn 25			575	16	66.9	Pale yellow
Chromium plate *(b)*	Hard			480	2	67.2	Extremely faint, slightly grayish, blue-white
Aluminum *(b)*	Commercial purity			550	1	84.3	Bright white
Monel, KR *(b)*	Ni 66.7, Cu 29.0, Al 2.9			580	7	58.8	Very pale, slightly grayish, orange-yellowish-white
Nickel *(b)*	Electrolytic			575	8	65.8	Very pale, slightly grayish, yellowish-white
Copper *(b)*	Electrolytic			585	26	71.3	Bright, orange-red

Footnotes:

(a) Calculated from reflection factor curves using standard observer data and I.C.I. illuminant "C" equivalent to daylight.

(b) Samples metallographically polished.

(c) Color buff; same as *(d)* followed by buffing on cloth wheel with chrome oxide coloring compound.

(d) Buff-cut; ground to No. 000 emery followed by polishing on cloth buffing wheel using commercial cutting compound.

(e) Electrolytically polished in citric-sulphuric bath for 10 min.

(f) Silver plate and sterling silver which were polished with a commercial silver polish before testing.

reflected from the surface. Silver is very bright because it reflects about 95% of the visible light falling on it. Pure iron appears dark in contrast because it absorbs over 40% of the incident light.

Each of the values determined from the spectral reflection curves has been listed in Table I; in the last column the visual appearance of the same samples when viewed in a specially constructed color-matching cabinet is indicated. While the "color factors" give a precise physical definition of the color, the "color description" is at best an average opinion of several observers of normal color vision.

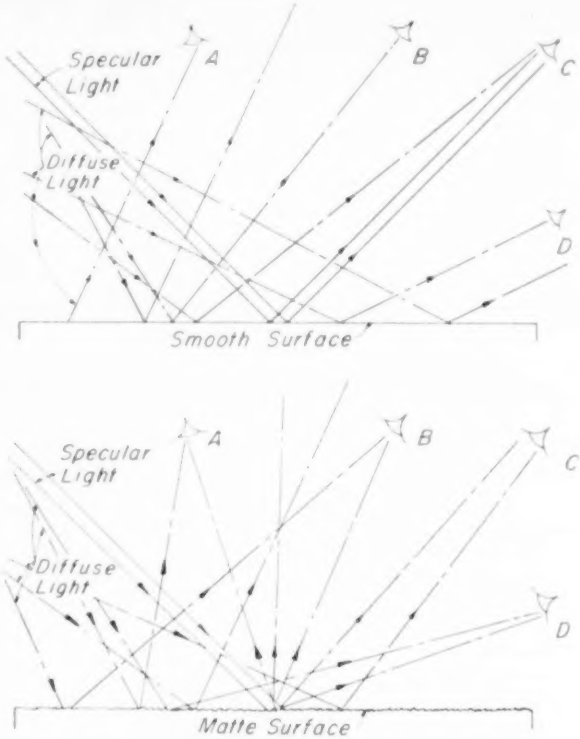


Fig. 3 — Diagrams Showing How Eye Receives Some Reflected Specular Light From a Smooth Surface Only When It Is in a Favorable Location Like C, but Gets Both Diffuse and Specular Light in All Locations From a Matte Surface

EFFECT OF COMPOSITION ON COLOR

Figure 1 and Table I show that the plain chromium stainless steels, regardless of carbon or chromium content, have almost identical spectral reflection properties and are indistinguishable in color. The reflectance curves show a tendency for all these alloys to reflect the red and yellow end of the spectrum very slightly better than the blue. The data indicate that these alloys should exhibit an extremely faint tan-to-yellow hue. The color is of such low "purity", however, that it does not seem to be detectable to the eye under ordinary circumstances.

The chromium-nickel stainless steels also show a tendency for greater absorption of the blue end of the spectrum. This absorption is a little more marked than for the nickel-free types, and gives a color of slightly higher purity. The very faint yellow-tan cast can be seen by most observers under good lighting.

Fig. 2 — Reflectance of 17% Cr and 18-8 Cr-Ni Stainless Having Various Types of Finish

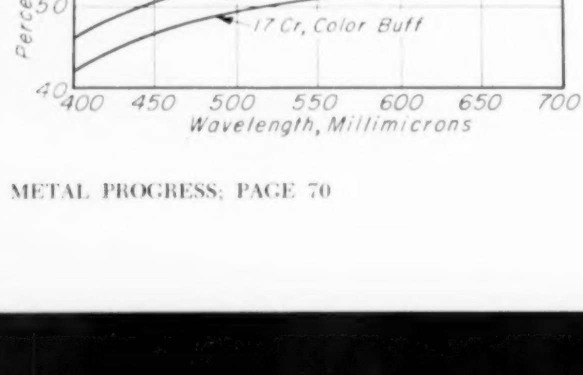


Table I also shows that substantial variations in chromium and nickel contents fail to affect the color appreciably. Increasing the chromium content from 0% (ingot iron) to 26% (Type 446) does not alter the hue or purity of color but causes the reflectance or brightness to increase slightly from 59% to 64%. Small additions of nickel have no effect.

However, when sufficient nickel is added to change the alloys from a ferritic to austenitic structure, the reflectance increases about 5%. Hue remains unchanged while the purity increases very slightly. Substantial increases in nickel beyond this point have no effect.

It will be noted that sterling silver and silver plate have the same dominant wave length as stainless steel; that is, their hue is predominantly yellow. The purity of the color is also of a very low order. However, they are much brighter; silver reflects nearly all the visible light that falls on it.

Turning to the other metals included in Table I and Fig. 1, nickel-silver has a pale yellow tint, more pronounced than either silver or stainless; in brightness it compares with the chromium-nickel stainless steels. Aluminum reflects all wave lengths with nearly equal intensity and, hence, has no discernible hue; in brightness it lies between stainless steel and silver. Chromium plate has a very faint blue cast which is detectable under good lighting conditions. Its brightness is the same as that of the chromium-nickel stainless steels. A slight maximum in the reflection factor curve at the blue end of the spectrum exhibited by this material is unusual.

Pure nickel has a readily distinguishable yellow hue, while Monel is yellowish with a very faint orange tint. Monel is slightly less bright than the plain chromium stainless steels. Copper, as may be seen from Fig. 1, is a highly selective reflector. It is red-orange in hue; the color is of high purity; and it is slightly brighter than nickel.

A chromium-manganese-copper alloy known in Germany by the trade name "Roneusil" is particularly interesting because it is claimed to be superior to the regular chromium-nickel stainless steels for flatware because it much more closely duplicates the appearance of silver. The spectral reflection factor curve for this alloy is actually midway between the bands for Cr-Ni and Cr stainless in Fig. 1. Other data listed in Table I show that in fact its color is the same as that of 18-8. This is borne out by examination of the alloy in the color-matching cabinet.

EFFECT OF FINISHING METHOD ON COLOR

The effect of polishing method on the color and reflectance of Type 430 (17% Cr) and Type 304 (18-8 Cr-Ni) stainless steels is shown in appropriate lines in Table I. Typical reflectance factor curves are illustrated in Fig. 2. The results seem surprising at first glance, since they show that some polishing operations like buffing, while they increase the smoothness of the surface, actually reduce the reflectance. See Type 430 *(c)* and Type 304 *(c)* and *(d)* in Table I. Simultaneously, the yellow hue is increased in purity. These effects could be readily verified when the samples were viewed in the color-matching cabinet; the buffed samples appeared darker and more perceptibly yellow.

Recent work has shown that buffing stainless steels appreciably increases the thickness of the oxide skin normally present on the surface. This heavier film may be responsible for the alteration in reflectance properties. It is interesting that electropolishing, on the other hand, results in reflectance values as good as may be obtained with a fine metallographic polish. See Type 304 *(e)*. This undoubtedly contributes to the attractive appearance of electropolished stainless steels.

From Table I it is apparent that differences in reflectance rather than in hue or purity are principally responsible for the different appearances of metals. Most of the common ones, except copper, gold, and chromium, are very faintly yellow in hue. Some metals such as silver are very bright due to their high reflectance; most others such as stainless steel, Monel metal and nickel-silver are darker because of their tendency to absorb some fraction of the visible spectrum. Finishing methods may affect the brightness of stainless steels. Procedures giving the smoothest surface, such as buffing, do not necessarily give the highest reflectance. Electropolishing appears to offer advantages as a finishing method where the highest reflectance is desired.

IMPROVEMENT OF APPARENT BRIGHTNESS

Since most metals, including stainless steels, tend to absorb some of the light that falls on them, it is interesting to consider if there may be any way to increase their apparent brightness. Perhaps some surface finish would catch light falling from any direction and direct at least part of it to the eye. Common lighting conditions usually include both diffuse illumination from walls (or sky, if outdoors) as well as direct or specular illumination from the light source (light fixtures or sun). When a smooth, flat surface is viewed in such light, the eye always receives some of the diffuse illumination, yet in positions such as A, B or D (Fig. 3a), it receives little or none of the specular light.

A matte or rough surface will scatter the specular illumination so that in any position the eye receives light both from the diffuse source and the specular source. The result is that under most lighting conditions the matte surface will appear brighter than a highly polished finish. If the surface is too rough, however, multiple reflections will occur within it which absorb light; the very dark appearance of deeply etched or sand-blasted surfaces

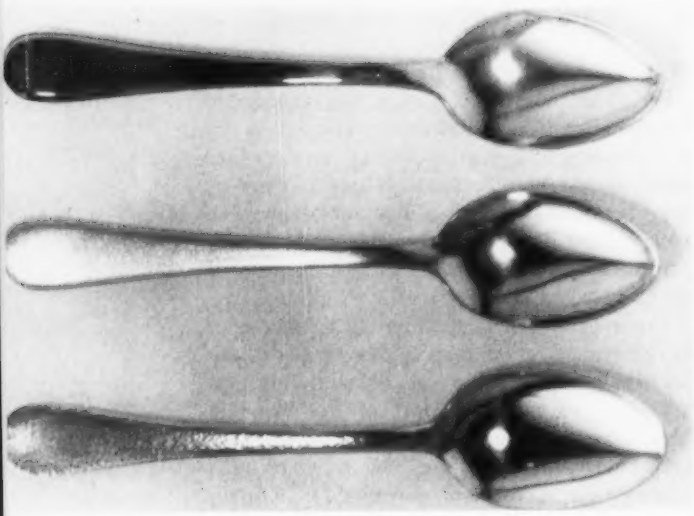


Fig. 4 – Three Stainless Steel Spoons Finished Variously and Photographed Under Spot Illumination. At top – buffed. Center – grit-blasted and electropolished. Bottom – hammered and electropolished

is a familiar example. The ideal combination would be a uniform matte finish sufficiently lustrous to avoid internal reflection.

Certain brushed finishes on stainless steel, such as the Tampico finish, operate in this direction. They are often more attractive in appearance than very smooth mirror finishes where large flat areas are involved. Another method which appears to be quite effective is grit-blasting followed by electropolishing. By itself, grit-blasting gives a matte and diffusely reflecting (though dark) surface. If followed by electropolishing the initially rough surface is smoothed enough to prevent internal reflection from reducing the brightness. Hammered and electropolished finishes give much the same effect.

Figure 4 shows clearly the marked difference in apparent brightness between a buffed spoon at top, one in the center which has been grit-blasted and electropolished, and the one below – hammered and electropolished. Except for occasional highlights, the spoon with the buffed handle appears very dark under the spot illumination used by the photographer. In contrast, the center one (grit-blasted and electropolished) has a handle which is quite bright because of its ability to catch and diffuse the spectral light. The hammered finish is intermediate in brightness.

Very striking and beautiful effects can be achieved in decorative dishes and trays by contrasting matte and flat polished areas. The diffusely reflecting areas may be etched finishes or embossed designs. The effective use of embossed or textured surfaces to increase apparent brightness is well illustrated in the photograph at the head of this article supplied by Rigidized Metals Corp. of Buffalo, N. Y., contrasting the flat polished areas of the edge trim and sink with the textured top and side.

SUMMARY

Broadly speaking, the differences in appearance of similarly polished surfaces of decorative metals are due primarily to variations in their absolute reflectance. Silver is an unusual metal in that it reflects nearly 95% of visible light, whereas most other metals, including stainless steels, may absorb up to about 40% of the light. Most metals tend to reflect the red end of the spectrum better than the blue and, depending on the extent of this difference, some have a faint yellowish hue generally of very low "purity". The plain chromium stainless steels have no visible hue and are slightly lower in reflectance than the chromium-nickel types. The latter have an extremely faint tan-to-yellow hue, the same as that of silver. Variations in the alloy content of stainless steels affect their color only slightly.

A few tests suggest that polishing methods such as buffing, while they increase the luster and image-forming characteristics of a surface, may actually lower the absolute reflectance slightly and increase the depth of the yellow hue. Where high reflectance is desired, electropolishing has merit.

The apparent brightness of a surface depends on its absolute reflectance and also on the nature of surface texture and character of the illumination. Where the illumination includes some light from a point source, as it usually does, a surface finish that catches and disperses some of the special illumination has a higher apparent brightness. Grit-blasting followed by electropolishing appears to have interesting possibilities. Embossed designs also are effective in brightening the appearance of articles and providing contrast.

While the absolute reflectance of stainless steels is an inherent property similar to and related to electrical conductance, the apparent reflectance is not so immutable and can be varied considerably. Where a high level of brightness is desired for decorative purposes, the proper choice of surface texture by embossing or other finishing methods can do much to enhance their natural beauty.

By W. R. BROWN, Metallurgical Engineer
Titan Metal Mfg. Co., Bellefonte, Pa.

The photomicrographs were all prepared by H. D. Hodge, metallurgist for Titan Metal Mfg. Co. Except where unetched, the etchant used for all samples was zephiran picrate.

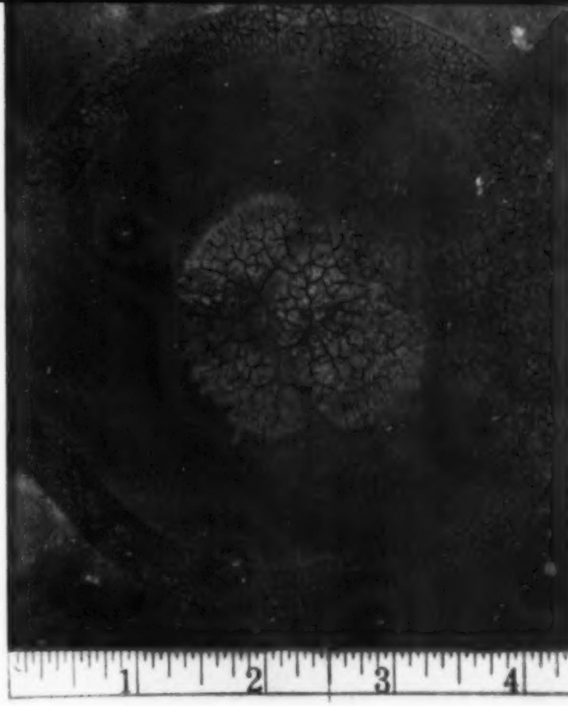


Fig. 1 – Heat-Checked Gate Block Used on a Horizontal Pressure Die-Casting Machine

A New Concept of Heat-Checking on Brass Pressure-Casting Dies

THE BRASS DIE-CASTING industry, although showing great promise as a rapid method of producing intricate and accurate parts of high strength, corrosion resistance, and attractive appearance, has developed very slowly, principally as a result of poor die and tool life. Many small cracks, known as heat-checks, form quickly in the dies and give the castings a rough, unpleasant surface. To repair this surface by grinding is expensive. Repair by welding is often more expensive than machining new dies; it is also only a temporary measure, because the dies usually break out again at the edge of the welds. Low die life and high die costs mean a low margin of profit in a highly competitive field.

These small cracks have heretofore been considered the result of thermal shock and thermal fatigue. "Shock" arises from contact of cold die with hot brass; the heat does not have time to diffuse into the die block and a temporary thermal head is built up in the surface layers. The surface skin of the die tends to expand but the cold and rigid underlying layers restrain it. This cycle is reversed between castings when the die surface cools and the underlying layers absorb heat. In casting brass at 1700 to 1750° F. the die surface reaches a maximum of about 1550° F., while the die block is only 1100 to 1300° F. 0.050 in. below the surface.

"Thermal fatigue" – the other reason given for the formation of the cracks – results from the reversing stresses of thermal shock, plus the stresses imposed by injection pressure. The present author does not believe that thermal fatigue *starts* the checks (although it undoubtedly increases their size) because dies will begin to check on similar parts at about the same rate whether the injection pressure is 6000 or 29,000 psi., as long as they are operating at about the same temperature.

Cracks can also be divided into two groups. First, cracks of a true thermomechanical nature occur in such places as corners, and are normal to other stress-raisers. These cracks identify themselves by their location, their relative straightness, and sometimes by their depth. They can frequently be avoided by making a change in design.

Role of Fatigue and Thermal Shock

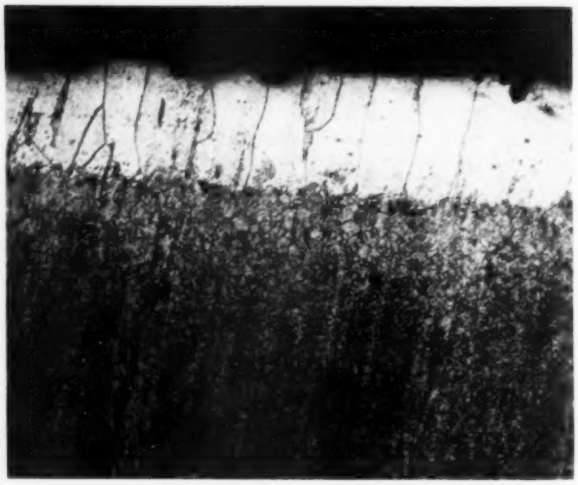


Fig. 3 – Simple Furnace Decarburization of Hot Work Steel, Showing Cracks, Fissures and Absence of Carbides. 100 ×

The second type of crack – the one which makes brass die casting relatively unprofitable – will be considered exclusively in the remainder of this paper. This defect is characterized by a maze of small polyhedral cracks known as heat-checks. A typical example – a gate block – reproduced at about full size, is shown in Fig. 1. These cracks originate as small star-shaped pits which increase in width and length as service continues but do not penetrate below a certain depth (probably determined by operating temperature) unless they are subjected to some mechanical stress. When this stress is great enough the cracks act as notches or stress-raisers.

Observations that seem to indicate that these heat-checks are not caused by fatigue or by thermal shock are as follows:

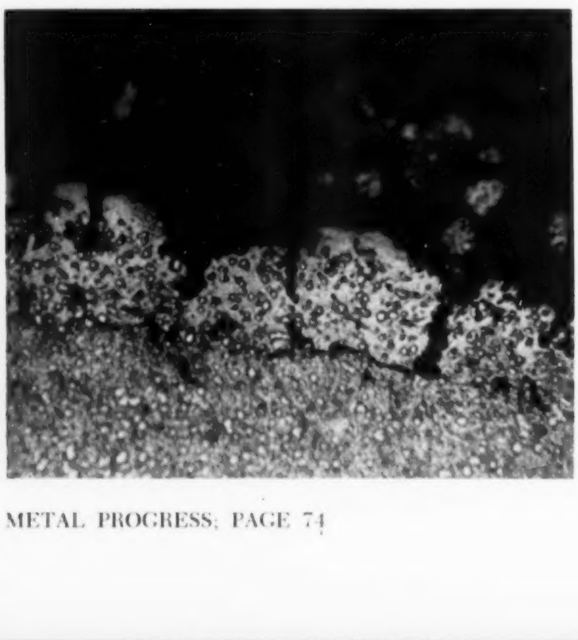
1. All ferrous metal parts, when in contact with molten brass, are subject to heat-checks, yet stirring bars, mold plates, and permanent molds have no imposed stress.

2. When thermal shock is minimized by heating the entire die block to the operating temperature, the tendency to heat-check is enhanced, not reduced.

3. Cast iron molds used in the glass bottle industry are exposed to higher thermal stresses than brass die-casting dies, yet they do not heat-check even after producing hundreds of thousands of bottles. Yet when this same iron is tried in brass pressure-casting dies, it will produce less than 500 castings before checking begins. The thermal gradient in the molding of glass bottles is from 900 to 2100° F. Brass dies operate between 600 and 1700° F.

4. True fatigue cracks should blend down in size from the most highly stressed area into the least stressed portion. Actually, as shown in Fig. 1, the checks occur only where the hot brass contacts the die material, and stop abruptly at the edge of the contact zone. Some portion of these areas of the gate block between the runners must be exposed to almost the same thermal conditions as those areas in actual contact with the molten brass, yet the protected areas show no checks except where the hot brass may have flashed or leaked out between the dies.

Fig. 2 – Hot Work Steel Immersed in Molten Brass for 45 Hr. Carbides are seen in the scaly layer; crevices and cracks extend into the unattacked steel. 500 ×



It appears, therefore, that heat-checks are caused by some form of corrosion resulting from contact with the brass itself.

THE EXPERIMENTAL PROGRAM

To determine whether hot work steel can be checked by hot brass alone, a sample heat treated to Brinell 532 was suspended in molten brass at 1710° F. for 45 hr., and cooled in lime. Figure 2 shows its microstructure. The cloudy material underneath the brass incrustation was a scaly layer, at first thought to be an oxidation product. Carbides can still be seen in this residue. Between this disintegrated material and the still-solid steel is a fissured layer about 0.001 in. thick. Incipient cracks can also be

seen penetrating into the unattacked base of steel. Despite lime cooling, the hardness of the sample was so high that it could only be cut by an abrasive cut-off wheel.

These observations – high hardness and presence of carbides in the affected layer – led to the conclusion that the attack on hot work steel by hot brass is not a form of oxidation or decarburization. The high temperature of the test softened the unattacked steel in the core of the sample to Rockwell C-20, but the outside affected layer was C-50 to 54. This fact leads to the supposition that iron has been removed from the hot work steel, leaving a highly alloyed chromium-tungsten matrix with a large number of carbide particles. Contrast

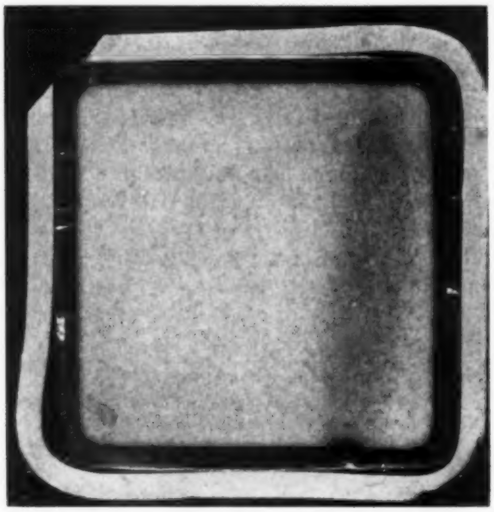


Fig. 4 – Cross Section of Sample Spun 2 Hr. in Molten Silicon Brass at 1700° F. Outside loose rim is polishing guard. Unetched; 5 ×

Fig. 2 with Fig. 3 which shows an ordinary decarburized layer on a hot work steel sample.

A number of identical samples were then made up from a square bar of hot work steel chosen because of considerable experience with it in actual service, and analyzing:

Carbon	0.34%
Manganese	0.26
Silicon	0.47
Chromium	1.43
Molybdenum	0.42
Cobalt	5.10
Tungsten	4.02

The samples were spun at 178 r.p.m. while immersed, thus continuously bringing them in contact with relatively fresh brass. If the corrosive element is in the brass, the time for a given reaction should decrease. The brass used analyzed 60.48% copper, 1.33% lead, 0.13% silicon, and remainder zinc.

Evidence of Corrosion Attack

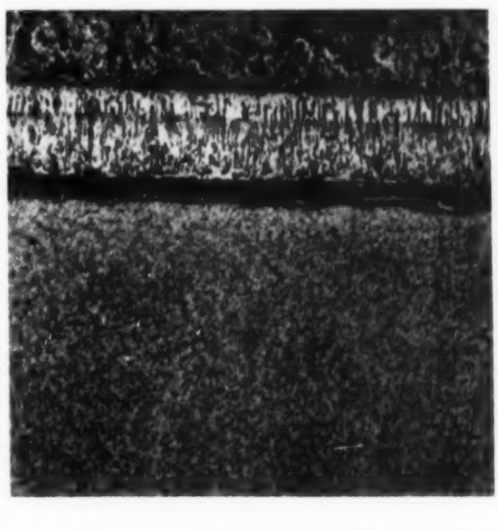
The cross section of the first sample, spun for 2 hr. in the molten brass, is shown in Fig. 4. The outside of the specimen has been severely attacked by the brass, resulting in a two-layered zone of a shiny, cracked diffusion product.

Figure 5 shows the microstructure of this layer. Surrounding the unattacked steel is a dark diffusion band, which is topped by a two-layered area of diffusion products. This area has numerous fissures filled with brass-colored material. When the time is increased from 2 hr. to 5, the diffusion zone penetrates almost twice as deep.

The probable formation of this diffusion zone is illustrated in Fig. 6. The brass attacks certain points on the surface of the steel. Then the attack progresses radially until the continuous, uniform layer is formed. The author believes that this picture illustrates the formation of a "heat-check". The cracks that form in this diffusion area progress, without stressing, into the unattacked steel as shown in Fig. 7. Many cracks such as these have been observed which are filled with brassy-colored alloy.

The surface appearance of the specimens after spinning is likewise interesting. After adhering brass and dross are rubbed off, many

Fig. 5 – Longitudinal Section of Sample Shown in Fig. 4. Steel base at bottom, followed by dark, solid diffusion barrier, two-layered zone of diffusion products and adhering brass. Depth of diffusion products is about 0.006 in. 100 ×



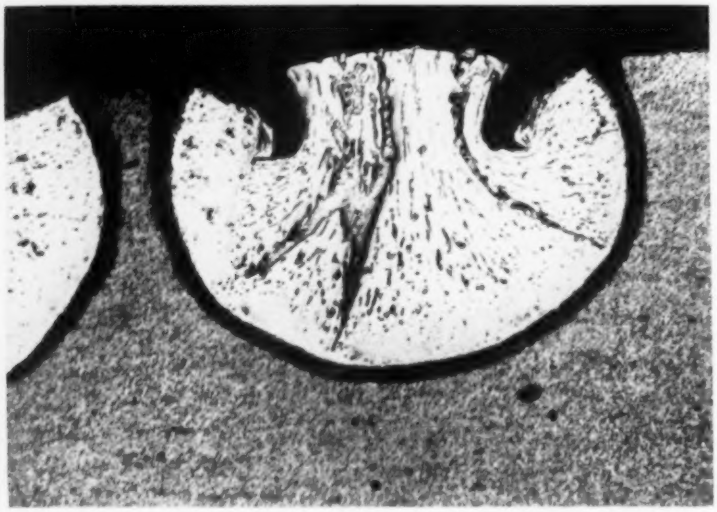


Fig. 6 – Evolution of Diffusion Layer. 100 ×

Since it has now been proved that molten brass alone can pit and crack hot work steel without any thermal shock or fatigue, these last two factors can be considered as contributing elements only rather than as the primary causes of heat-checks. With this fact established, it should be much simpler to find a corrosion inhibitor, or to tailor-make a die steel that will be corrosion resistant, than to continue the fruitless search for a die material having unnecessary and impossible physical properties for resisting overemphasized stresses.*

Figure 9 clearly shows carbides in the diffusion layers; Fig. 3 shows their absence in surfaces of such steel heated in air. This eliminates oxidation as the cause of the corrosion. Moreover, the molten brass mixtures No. 3 and 4 containing added oxides did not attack any more severely than those mixtures that were free of oxide.

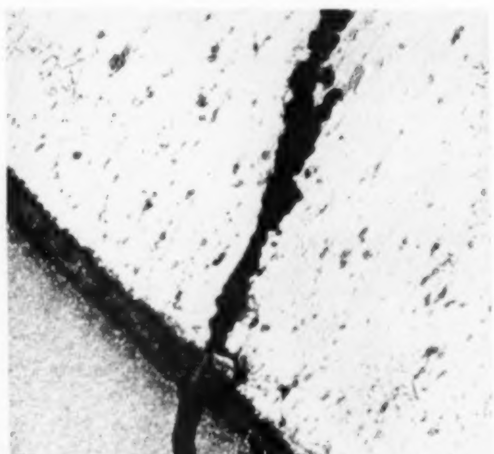
The next corrodent under suspicion is the zinc contained in the brass. Micrographs of

cracks show up, as in Fig. 8. This damage increases with time. Anyone familiar with brass die casting will note the similarity of these cracks to "heat-checks". Examination of the polished and etched surface of such a steel sample at high magnification indicates that molten brass seems to attack the ferrite matrix preferentially, leaving the carbide spherulites.

EFFECT OF BRASS COMPOSITION

To determine whether the purity of the brass had any effect on the rate of attack, four brass samples were made up using only pure iron-free metals and chemicals. Separate steel samples were spun for 2 hr. in each of the melts, but no difference in the depth or type of attack could be seen in the four steel samples. After these tests the brasses analyzed as shown in Table I. These analyses proved that iron was dissolved from the steel surface. Calculations show that the iron found in the brass was equivalent to about 15% of the original steel sample.

Fig. 7 – Crack Penetrating Through Diffusion Barrier Into Remaining Steel. Zinc-iron alloy at upper right; unattacked steel at lower left; diffusion zone between. 250 ×



*Editor's Footnote – Another method of solving the problem would be to make or line the die with material which is insoluble in liquid zinc. This is not easy to do. "Liquid-Metals Handbook", 2nd edition, lists only dense graphite, silicon carbide and aluminum oxide as materials with "good" resistance to attack by zinc at temperatures below 1650° F. (By "good" is meant less than 1 mil penetration per year.) Of the refractory metals, columbium, zirconium, tantalum, tungsten, chromium, titanium, and vanadium are listed in that order; chromium is classed as of "limited value" (penetration from 1 to 10 mils per year). An 80-20 Mo-Fe alloy had "good" resistance at the melting point of zinc (790° F.).

galvanized steel sheet show a distinct similarity to the diffusion layers formed on the hot work steel samples immersed in molten brass. Other facts harmonize with our experimental results: Molten zinc dissolves iron at a rate increasing with temperature. It forms various iron-zinc compounds which appear as two layers on the surface of the iron. (Although only two layers are readily visible, a number of iron-zinc compounds are formed, which are porous, hard, and brittle, similar to the layers found on the hot work steel samples.)

If, as the author believes, the primary cause of heat-checks in brass die-casting steels is the formation of these iron-zinc compounds, the great amount of work done by galvanizers should be of much benefit to brass die casters and toolsteel manufacturers. The galvanizers have found that iron-zinc compounds form very quickly. Immersion of only 0.05 sec. in molten zinc will form a microscopically detectable layer of these compounds. Therefore, it is apparent that the time required to make a brass die casting is sufficient for their formation, especially when the high temperature of the brass die casting operation is taken into consideration.

Table I – Analysis of Brass Melts After Exposure to Steel Specimens

Melt	Cu	Pb	Fe	P
1. 61 Cu, 39 Zn	60.96%	—	0.291%	—
2. 61 Cu, 38.2 Zn, 0.8 Pb	60.36	0.71%	0.224	—
3. Same as No. 2, plus PbO, CuO and ZnO	60.71	0.61	0.216	—
4. Same as No. 3, plus CuP	60.82	0.93	0.244	0.012%

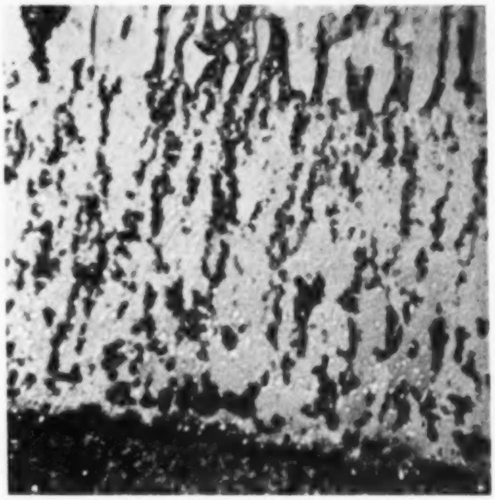


Fig. 9 – Hot Work Steel Sample Spun for 5 Hr. in Molten Brass. Steel at bottom; note carbides in inner diffusion zone. 500 ×

The galvanizers report that carbon above 0.20% and silicon above 0.20% in the steel rapidly increase the attack by zinc. Yet all the common hot working steels contain from 0.35 to 0.45% carbon, and from 0.35 to 1.00% silicon. Thus if the premises of this paper are correct, there are many check points established by galvanizing experience which can be used in developing a hot work steel that will resist the corrosive action of zinc and formation of brittle compounds.

As a further correlation between galvanizing and brass heat-checking, an interesting experiment may be cited. In galvanizing, it is known that the presence of silicon increases the amount of the iron-zinc compounds. It is also known that aluminum decreases the tendency for their formation. Figure 5 shows the amount of compound formed in 2 hr. by regular brass containing neither aluminum nor appreciable silicon. The compound layer is about 0.006 in. thick. This brass analyzed 60.48% copper, 1.33% lead, 0.13% silicon.

A silicon brass in common use for die casting contains 0.75 to 1.25% silicon. A heat was made up to 0.73% silicon (64.19 Cu, 0.39 Pb, remainder Zn), and a steel

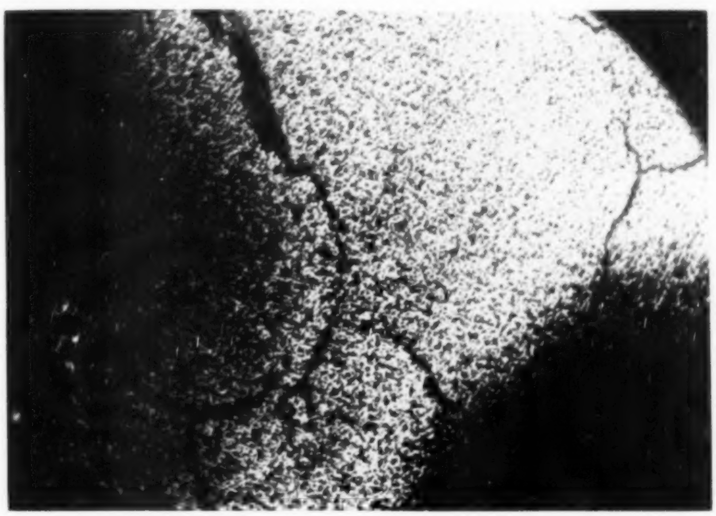


Fig. 8 – Outside Surface of Sample Spun for 5 Hr. Unetched; 50 ×

sample was spun in this analysis under the same conditions as the sample shown in Fig. 5; its microstructure is shown in Fig. 10. Note that the depth of the iron-zinc diffusion products is more than twice that of the silicon-free brass of Fig. 5.

Fig. 10 – Sample Spun in Molten Silicon Brass. Steel at bottom; brass at top. Depth of diffusion products is about 0.015 in.; compare with Fig. 5. 100 ×

Another heat was made up, replacing the silicon with 0.62% aluminum (65.58 Cu, 0.51 Pb). The microstructure of a sample of steel spun in this brass is shown in Fig. 11. This shows only a thin, one-layered diffusion zone, which may be an aluminum-iron compound that prevents the zinc from diffusing into the steel.

These last two photomicrographs show pretty clearly that there is a great deal of similarity between the galvanizing process and the attack of molten brass on hot work die steel.

SUMMARY

The fine maze of cracks occurring on brass hot working tools is known as "heat-checking", and has heretofore been attributed to thermal fatigue of the surface layers of the die material.

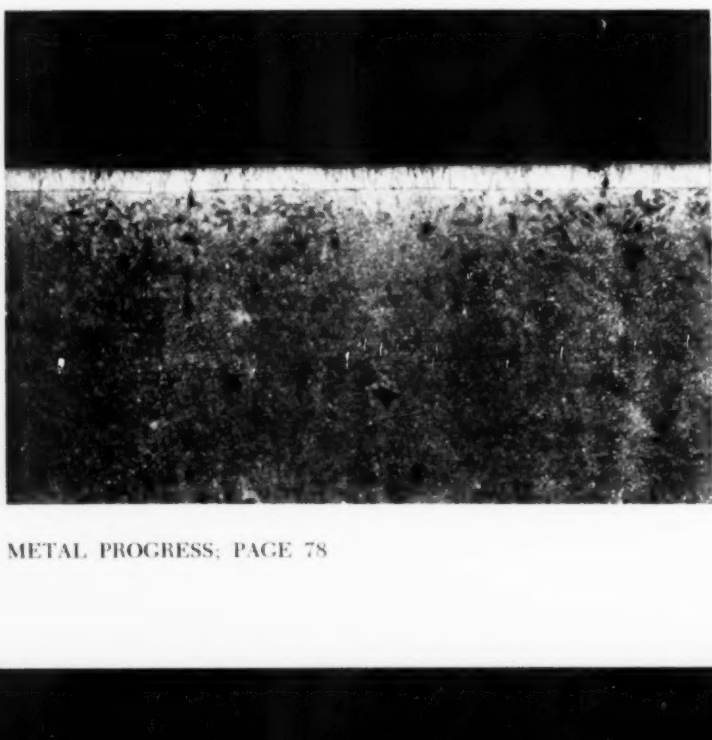
However, today's highly alloyed steels and high-temperature jet alloys generally have adequate physical properties at brass fabricating heats to withstand the imposed stresses. Yet, of the great number of these alloys tested in service, none resisted heat-checking as well as hot work steel.

Experiments indicate that such cracks develop, instead, by the formation of a thin layer of a hard and brittle intermediate alloy. This alloy is thought to be an iron-zinc compound formed as a result of intermetallic corrosion of the die steel by the zinc in the brass.

A simple and quick laboratory procedure has been developed for determining the resistance of the die material to this attack. The activity of various brass alloys may also be determined, with the possibility of finding suitable agents that will act as inhibitors or as diffusion barriers for the zinc. Such procedures require only a few days' time rather than the lengthy, inconclusive tests now in vogue.

Much can be learned about such corrosion and cracking by studying the process of galvanizing, which might even yield some ideas for developing an improved hot work die steel.

Fig. 11 – Sample Spun in Molten Aluminum Brass. Steel at bottom. Depth of diffusion about 0.002 in. 100 ×



By J. R. TOWNSEND
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A Dynamic Program for Conservation

THE LIST OF resources which today separate the "have" from the "have-not" nations includes not only such traditional items as coal, iron, oil, and timber, but also such specific elements as cobalt, columbium, beryllium, tungsten, tantalum and even nickel. These elements are the foundation of our present civilian and defense effort. The present and future of our civilization now depend upon hard, strong, tough, heat resistant metals that will maintain their shapes at high temperatures and at high speeds. But the best figures available show that we have only about half the alloys needed for an all-out war!

Nickel, cobalt, tungsten, columbium and tantalum ballooned in importance with the appearance of the jet engine and the combustion turbine. Beryllium's new-found importance results from its role in our atomic energy program.

For working parts of jet engines and combustion turbines, simple nickel-bearing alloy steels may be used up to 1500° F. Beyond that point, alloys or compositions based on nickel, cobalt, tungsten, columbium and tantalum must be employed.

Today more jet than conventional engines are being produced for aircraft. Gas turbines now are being designed for locomotives, for ship propulsion and deck use, and for pipeline pumps. Their uses will be extended. The needs for critical materials for peacetime pursuits are great. For all-out war the demand would be about twice what we have available.

This situation is serious but, fortunately, not hopeless. A dynamic, coordinated program of conservation (using the word in its broad sense) can give us a hedge on these shortages.

Conservation in its best expression is achieved by employing the unique characteristics of each essential substance to the greatest degree consistent with sound design and processing. This ideal of equivalent or better performance has none of the connotation of the German "ersatz" of World War II. Instead, this new concept casts conservation in a dynamic and objective role.

Basically, there are four ways by which conservation can overcome the shortages of these six strategic elements. They are *(a)* substitution of more plentiful elements, *(b)* reprocessing and redesigning products, *(c)* more standardization, *(d)* opening up new sources. Let us examine these four methods.

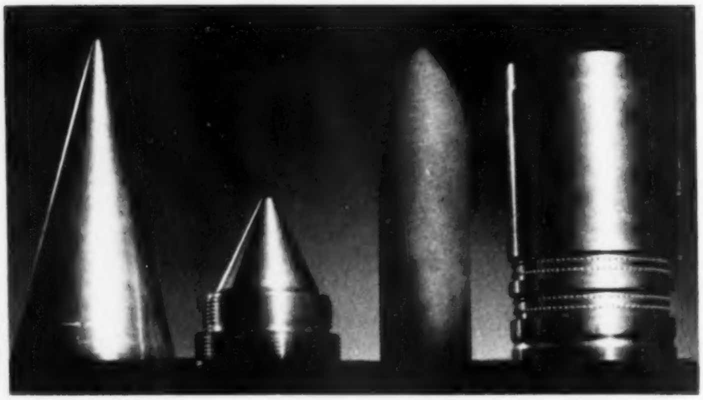
SUBSTITUTION

It is estimated that 25 to 50% of the civilian needs for these critical elements can be avoided by substitution without serious degradation in product. Even higher percentages of replacements are possible for military needs, thus spreading the available materials to turn out more defense units.

Conservation by substitution of equivalent or even superior materials is well known. Inferior materials have sometimes been used, but design changes frequently make the inferior material usable without noticeable degradation in quality or life of the product. The classic example is the automobile engine crankshaft, where a heavier casting satisfactorily replaces a lighter forging.

Complete elimination of a scarce metal from a conventional use is the ultimate in conservation. This is not unknown. Lacquered cans rather than "tin" cans approach this ideal. An even better illustration will be given in an article in the July issue of *Metal Progress* describing the solderless contacts devised by Bell Telephone Laboratories.

In any event, substitution of one material for another in any product is a complicated process. The substitute must be tested to see if it will perform as satisfactorily and last as long as the original material. We need new and improved performance test methods which will tell a processor quickly if the substitute can do the



Anti-Tank Shell With Tungsten Carbide Core. From left, the windshield, nosepiece, core, and body, less rotating bands. (Courtesy Carboloy Department of General Electric Co.)

job. *Metal Progress* has printed two notable articles recently (August and September 1952) by A. L. Boegehold, in which he outlines the steps whereby safe changes in automotive parts can be made.

The need is great for development of new test methods. For instance, there is considerable doubt as to whether the present test for armor is thoroughly reliable, particularly on nickel-free substitutes. Again, most everyone has engaged in the perennial debate about the meaning of the notched-bar impact test.

REPROCESSING AND REDESIGNING PRODUCTS

Another effective way of husbanding critical materials is by reprocessing materials or by redesigning products. Processing improvements give us immediate savings. The better the processing, the less the scrap and rejections, both of which cause a large drain on our store of crucial elements.

Change in design of products may offer new use and choice of materials. For example, half of the projected demand for tungsten has been allocated to anti-tank projectile cores, in the form of tungsten carbide with 16% cobalt as binder. This type of projectile was first used by the Germans at Kasserine Pass to defeat American armor. But now the U. S. Army's Ordnance Department has come up with other methods of penetrating armor; current tests will ascertain their worth. If the substitute projectile designs are successful, there will be enough tungsten for all. Design, in this case, is a powerful factor in conservation.

Design changes can often be made when the engineer has a thorough-going knowledge of the need for conservation. He can be informed by the technical press, by participating in conferences and by directives from his chief. However, beyond a certain point, we cannot rely on such voluntary help and must require that certain restrictive measures be taken. When acute stockpile shortages of vital material exist, the theory of *laissez-faire* must give way to the greatest good for the greatest number. If kingdoms are lost for want of a nail, it seems important that we ration nails in time of danger.

Standardization offers two immediate beneficial effects in conserving critical materials. First, by reducing the number of sizes to be made, we get quicker, more efficient use of our vital materials. Second, it substantially reduces the amount of vital materials which are tied up on shelves in inventory. Third, standards reflect the endorsement of accumulated technical experience and hence conserve effort that might otherwise be squandered on repetitive experimentation.

STANDARDIZATION — AN AMERICAN SKILL

Standardization has been America's greatest contribution to science and production. The role of standards and the application of engineering skill have been overshadowed by the role of pure science, particularly in such dramatic developments as radar and the atomic bomb. But it has been necessary in all great developments for the engineering designer to collect scientific knowledge and apply it to mass production.

When I visited Germany in 1945 to study technological developments, I was astonished by the wealth of scientific knowledge and data that had been used in the development of new weapons. They had prototypes of many weapons, which – if mass produced – might have changed the outcome of the war. The failure was in technology; the Germans simply did not understand modern production methods. They did not have standard quality control or advanced production machinery. I even found in many German plants, in accordance

with old custom, a drawer of assorted hand files at each worker's station.

But today national standards of dimension, fit and nomenclature are insufficient. Our standards must be extended beyond our own borders, to provide an international unity of purpose in conservation of vital materials.

A beginning was made in 1948 when representatives of Great Britain, United States and Canada agreed on standards for most screw threads. It seemed wise in my early work at the Office of Defense Mobilization to extend this work to other basic standards. So a second meeting was called in New York at which international standards were considered for other screw threads, for threads for gas cylinders and fitments, and for nomenclature. At a third meeting preliminary agreement was reached on standardization of cylindrical fits, and the problem of universal drafting standards will be taken up probably this fall.

The work of this group will place the English-speaking nations of the North Atlantic on a common level of understanding. Each will be able to make the others' products. All the parts will fit and work together. Faster production, smaller inventories will result. Conservation of vital material will be aided immeasurably.

NEW SOURCES OF CRITICAL MATERIALS

"Simply find some more" seems to be the most elemental method of overcoming shortages. Unfortunately, metals are not replaceable in nature as are carbonaceous materials. Metals pass from richer to poorer deposits. It becomes increasingly difficult to recover metals from low-grade ores, which, ironically, are in greatest abundance.

Nowhere is there a more striking example of this than in the nickel, cobalt and chromium content of the laterite ores in the tropics. Cuba alone has 3,000,000,000 tons of ore, estimated to contain 0.9% nickel, 0.3% cobalt, and 1.5% to 2% chromium with 35% to 40% iron. This ore has been worked for iron since the early 1900's. During World War II, the American government sponsored a project there by the Nicaro Co., which is now producing 15,000 tons of nickel annually. New processes for the recovery of these elements should be devised and tested. If they are successful, we will have all the nickel, cobalt and chromium, not to mention iron reserve, we will need for hundreds of years. But even with intensive study and development, production cannot be expected until 1957 or 1958 at the earliest.

This seems an appropriate place to examine the peculiar situation of titanium. Although there is as yet no civilian demand for titanium, it is superior to any other metal for many military uses. It is excellent for armor. It is essential for supersonic missiles whose casings are heated by air resistance to 500° F. Aluminum collapses under this heat unless heavy refrigeration units are used. Titanium survives this temperature without effort. Because of its stable performance at temperatures up to 800° F., titanium also can be used for blades of turbocompressors and for the skin of supersonic planes.

Titanium is not necessarily a substitute material, but it will create its own uses and as such will make better weapons and add to our national strength. There is an abundance of titanium ore in the U. S.

In my opinion, the greatest challenge today to the continuance of our expanding material civilization is our supply of ferro-alloys and refractory metals. Much has been done to overcome this grave problem.

Meetings and conferences on nickel, cobalt, and structural steel for welding and riveting have been attended by engine builders, steel manufacturers, metallurgists, nickel producers, electrical heating experts, corrosion experts, vacuum tube experts, nonferrous alloy manufacturers, gas and jet engine builders, automotive engineers, aeronautical engineers, and government representatives. More than 30 specific suggestions were made for conservation of vital materials in these meetings.

Various organizations outside the Government also have been actively engaged upon conservation problems. One is the Minerals and Metals Advisory Board of the National Academy of Sciences. Its budget last year was $250,000. More than 200 experts served on its panels. This board investigates problems, issues reports on a high technical plane and circulates them within and without the Government. Its reports range from general suggestions of an over-all nature to specific substitute alloys and their uses.

With private and governmental organizations working in concert, there is no reason why we cannot conserve and even enlarge our stock of critical materials. Cooperation is no problem. With national survival at stake, men find it easy to work together.

Giant for Giant

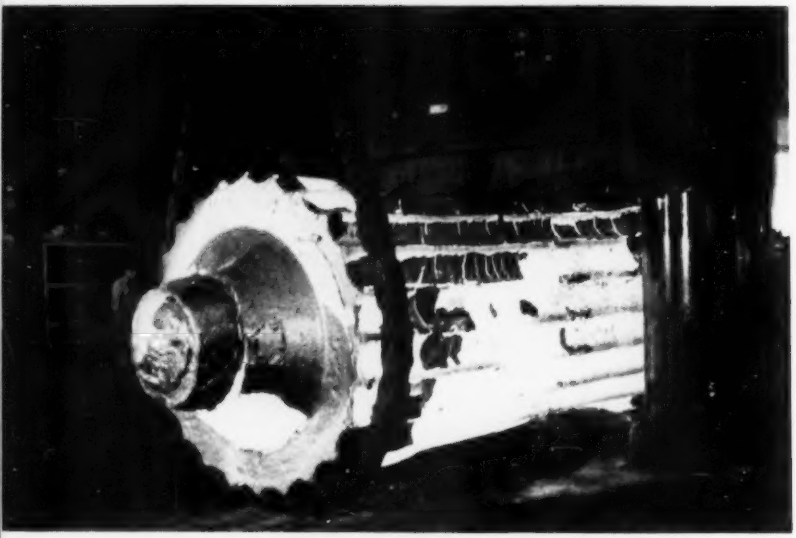


Fig. 1 – Ingot Mold Flutings Are Still Visible as First Forging Operation Is Performed on 275-Ton Ingot at Bethlehem Steel Co. in Producing One of 18 Column Sections for a 50,000-Ton Die-Forging Press for the Aircraft Industry

A SAMPLE of some of the production difficulties to be expected in carrying through the Air Force heavy-press program (see *Metal Progress*, March 1953, p. 111 and 186) was met by Bethlehem Steel Co. during the forging of a column section for one of the 50,000-ton presses of the program. Beginning with a round corrugated ingot weigh-

Fig. 2 – Scene During Second Forging Heat in 7500-Ton Press. The once-round ingot by now has been forged into rectangular shape and is being elongated

Fig. 3 – Fourth Forging Heat Under the Press. The column section has grown to 70 ft. in length. Press here is reducing main body width to 44 in.

Fig. 4 – Completely Forged and Now 110 Ft. Long, the Piece Is Given Final Straightening in a 6500-Ton Press

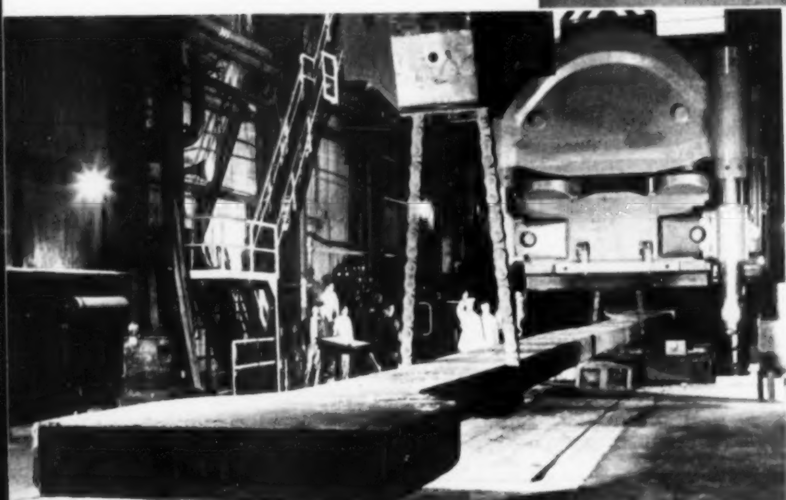


Fig. 5 – After Final Straightening, Excess Metal Was Trimmed From the 145-Ton Forging With This Automatic Gas Cutting Machine, in Which an Electronic Tracer Follows a Chalk-Drawn Pattern

ing 275 tons (Fig. 1), forging of the column section was completed after a series of five individual heating and forging operations under a 7500-ton press. Its final shape is that of a flat dumbbell 110 ft. long, 16 in. thick throughout, with a main body width of 44 in. flaring out to a maximum width of 100 in. at the ends.

Special handling equipment was made so that two large cranes could carry the forging from the heating furnace to the press after it was forged to 40 or 50 ft. This consisted of an arrangement of supports at regular intervals along the length of the steel to prevent the bending that would be induced by its own weight while the steel was at forging temperature (2300° F.). When the forging had been elongated beyond the length of the 37-ft. heating furnace, only one end was heated to forging temperature and worked at a time. Hoods of special design were used to retain as much temperature as possible in the section outside the furnace.

After forging, the column section was annealed for one week in a special furnace 120 ft. long. Straightening was done in another part of the plant, and a set of three railroad cars had to be rigged to transport the forging. Heating for straightening and stress-relieving was done in a furnace specially built for the purpose. The cutting machine and layout facilities shown in Fig. 5 above were installed particularly for this job.

Metallography of Hafnium*

By H. P. ROTH
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Cambridge, Mass.

HAFNIUM is a metal rare enough to deserve a general introduction to the readers of *Metal Progress*. It is heavier than lead. When pure, it is fairly ductile; it has a close-packed hexagonal structure and a white metallic luster.

Hafnium derived its name from ***Hafnia*** – the ancient Latin name for Copenhagen. It was there that the element was discovered in 1923 by D. Coster and G. von Hevesy, who proved its existence in zircon by spectrographic analysis. It was not unexpected; according to previously advanced theory by Neils Bohr, such an element should exist in close association with zirconium.

These two elements are so alike in chemical characteristics that methods for separation present great difficulties. For this reason hafnium has been known as the nuisance element in zirconium, and the expression "zirconium contaminated with hafnium" is not uncommon. E. C. Miller in last month's *Metal Progress* (p. 67) tells of the eventual success in separating the two elements on a commercial scale.

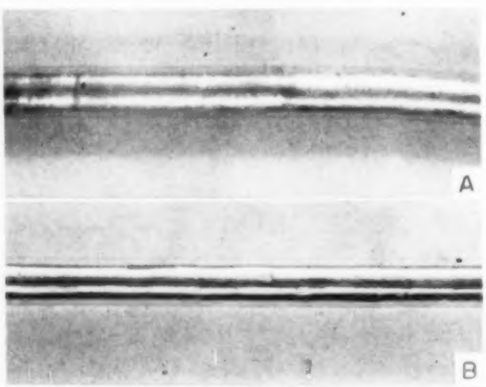
The earth's crust contains about 1 part in 100,000 of hafnium. It is never found in the free state. Lee has thoroughly reviewed the spectrographic data on 70 minerals, mostly varieties of zircon, in which hafnium ranges from 0.2 to 15%. DeMent and Dake, in their book on "Rarer Metals", say that at least 0.02% of the earth's crust is composed of zirconium; thus the element appears to be more abundant than nickel, copper, zinc and lead, which are so-called "common metals". However, the facts that zirconium minerals are so widely scattered and that the metal is so costly to prepare place zirconium in the category of uncommon metals. It can readily be seen why hafnium is still more costly.

Apparently no hafnium metal was available in the United States in 1931, but hafnium dioxide and hafnium chloride could be purchased in small amounts for approximately $25 a gram. A small sample of metallic hafnium had been presented by G. von Hevesy to the American Museum of Natural History in New York as part of the element collection.

The main differences between hafnium and zirconium are that the density of the former is about twice that of the latter, and that hafnium has a much higher neutron absorption cross section. Because of the high absorption value, hafnium is undesirable for certain atomic energy applications and must be removed as completely as possible from zirconium intended for such uses. Structurally, hafnium under the light microscope appears similar to most crystal-bar zirconium produced by the iodide process.

Experimental Procedure – The metal available for this investigation consisted of four types of crystal bar, namely: A – pure hafnium;

Fig. 1 – Appearance of Crystal Bar as Received. A – Hafnium; B – 98% hafnium, 2% zirconium; C – 76% hafnium; 24% zirconium



*This work was carried out at the M. I. T. Metallurgical Project under Contract No. AT (30-1) – 981 with the U. S. Atomic Energy Commission.

B – 98% (by weight) Hf, 2% Zr; C – 76% Hf, 24% Zr; D – a control sample of fairly pure zirconium crystal bar which had been degassed.

The external appearance of the three hafnium bars is shown in Fig. 1. The pure hafnium (top) and the 98% (center) have smooth surfaces. The 76% hafnium looks like zirconium crystal bar. These bars were procured from the Philips Co. of Holland in 1949.

Samples taken from the rods "as received" were polished and examined microscopically. The four rods were then reduced by cold swaging to 50% in diameter and again examined microscopically. After cold working and electropolishing, pieces from all four rods were wrapped in tantalum foil and sealed in a quartz tube under vacuum at a pressure of 2.5×10^{-6}. This precaution was taken so that the surface of each bar would be fairly well preserved during annealing and only a short electropolishing treatment would be necessary for re-examination, thus avoiding working effects that might be introduced by emery paper polishing. The samples were annealed in a resistance furnace under vacuum and quenched in water. Annealing treatments consisted of 2 hr. at 500, 800, and 1100°C. (930, 1470 and 2010° F.).

Microstructures – Photomicrographs of the pure hafnium (Bar A) "as deposited", taken in bright and polarized light at 100 ×, are shown in Fig. 2. About a third of the width of the original bar is shown; one longitudinal edge of the sample can be seen in a corner of the pictures.

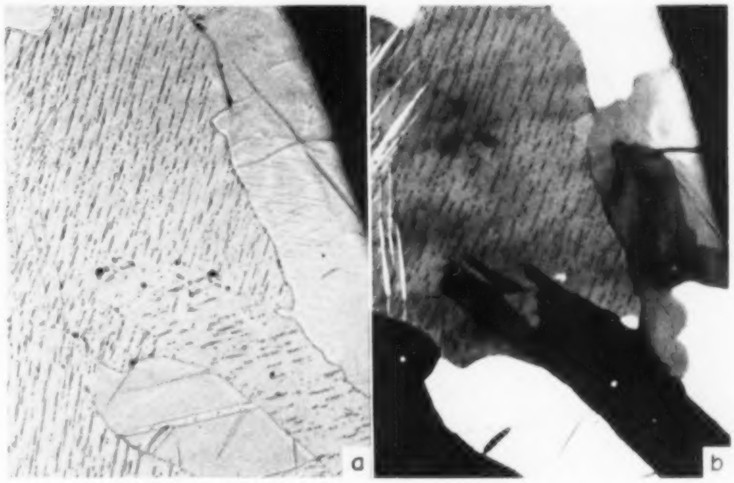


Fig. 2 – Longitudinal Section of Pure Hafnium (Bar A) as Received. (a) Bright light; (b) polarized light. 100 ×

Under polarized light (Fig. 2b) subgrains are evident, as well as a texture pattern which consists of an etching effect varying in degree and direction. It appears as fine pitting or parallel stringers of minute inclusions, and commonly occurs in zirconium, hafnium and other metals which have not been annealed to a uniform equiaxed grain structure.*

The texture pattern is extremely pronounced in metallographic samples of zirconium to which varying amounts of certain other constituents have been added, such as oxygen and nitrogen. Since it seems to be accepted

*The term "relaxed" has been applied to such a structure, and the reason therefor was explained in a somewhat facetious vein before a small conference of metallographers held at Columbia University School of Mines in September 1952, about as follows:

Relaxed, Equiaxed Grain – Annealing, producing recrystallization and grain growth within the subject family of metals, brings about such a satisfactory structure for optical examination with a microscope that it is a pleasure to prepare the polished surface, a pleasure to behold the lack of distortion, apparent lack of impurity – lack of unjustifiable preference. All things appear to be in a state of harmony within that resolved binocular world. Boundaries easily move where they should according to the laws of all things in accord. This is not a single crystal to be called a hermit and rotated so as to put forth the angles or face one chooses to see. This is polycrystalline and therefore displays special talents for gregariousness in order to be serene when viewed from any angle. No straining is evident, no twisting, no screaming, pushing or pulling; only a smooth and orderly arrangement of "invisible" atoms seeming to have floated into their convenient and proper positions without so much as a sound or a sidestep.

Application of the word *relaxed* may not be in strict agreement with the definition of the Subcommittee on Relief of Residual Stress which says in Metals Handbook (p. 237) "Treatments such as . . . . . annealing . . . . will not be considered stress-relief treatments." However, one of the definitions of annealing given on p. 2 of that same authoritative volume includes "relief of residual stress . . . ."

Stress can mean "the cohesive force or molecular resistance in a body opposing the action of forces such as tension".

"Tension is a stress due to a force (either of two balancing forces) causing, or tending to cause, extension."

"Tenseness" is defined as "a condition of tension".

"*To relax*" is defined as "to abate in tenseness".

Relax is a good word.

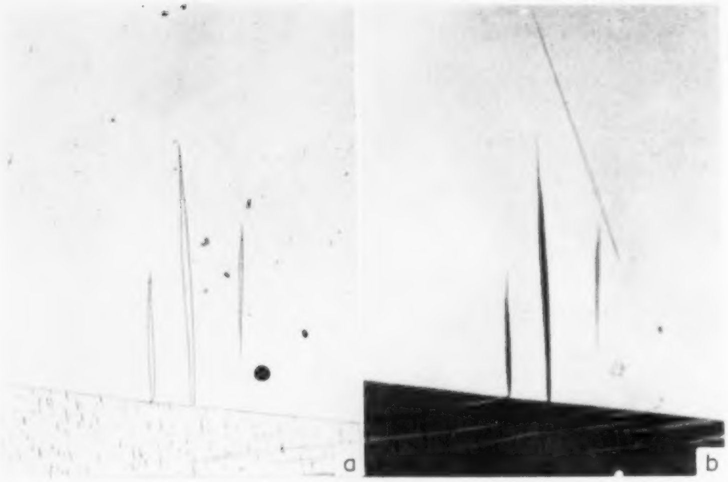


Fig. 3 – Longitudinal Section of the 98% Hafnium (Bar B). (a) Bright light; (b) polarized light. 100 ×

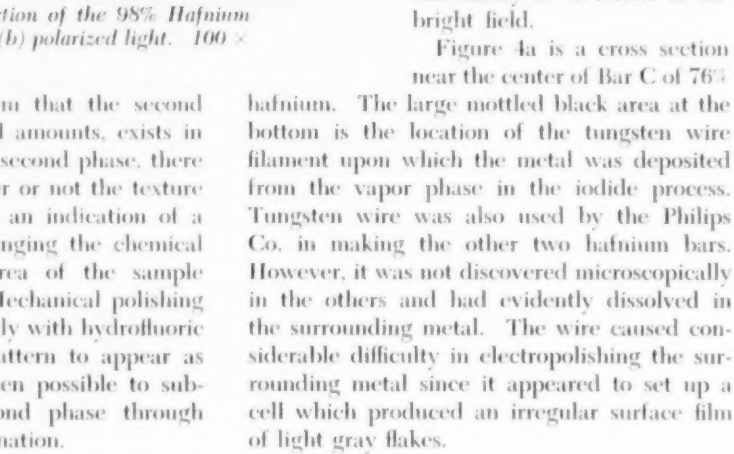
by students of the problem that the second constituent, added in small amounts, exists in solid solution and not as a second phase, there is a fine point as to whether or not the texture pattern can be considered an indication of a concentration gradient changing the chemical response from area to area of the sample during electropolishing. Mechanical polishing and chemical etching, mainly with hydrofluoric acid solutions, have caused the pattern to appear as pronounced ridges. It has not been possible to substantiate the existence of a second phase through other means such as X-ray examination.

There is another and more valid explanation of the texture pattern – namely, that it is the result of transformation, where platelets of similar orientation join to form each massive grain, sometimes producing feathery, irregular grain boundaries. These may be called unrelaxed grains.

Figure 3 shows the 98% hafnium (Bar B) at 100 × in both bright and polarized light. Only one grain boundary appears as a straight line running nearly horizontal. This microstructure conforms very neatly with the macrostructure of the exterior of the bar shown at the middle in Fig. 1. The smoothly polished crystal on top of Fig. 3a and b was so large that only a portion of the grain is covered. The broad, sharp lines are due to deformation during cooling. Below this boundary is another grain containing twins at a different angle and lines of shallow pits previously called texture pattern. The twins are seen to have changed orientation and direction within this crystal, indicating distortion. In sampling the rod, a cut was made through this crystal with a jeweler's saw just below the bottom of this view. Several of the twins that are shown by polarized light in Fig. 3b can hardly be detected in the bright field.

Figure 4a is a cross section near the center of Bar C of 76% hafnium. The large mottled black area at the bottom is the location of the tungsten wire filament upon which the metal was deposited from the vapor phase in the iodide process. Tungsten wire was also used by the Philips Co. in making the other two hafnium bars. However, it was not discovered microscopically in the others and had evidently dissolved in the surrounding metal. The wire caused considerable difficulty in electropolishing the surrounding metal since it appeared to set up a cell which produced an irregular surface film of light gray flakes.

Fig. 4 – Structure of 76% Hafnium (Bar C). (a) Transverse section under bright light; mottled black area at bottom is tungsten wire filament upon which the metal was deposited. 250 ×. (b) Longitudinal section under polarized light showing strain effect from cold work. 100 ×



In Fig. 4a, the small, faint, birdtrack markings are remains of the deepest paper polishing scratches which were not entirely removed by the electropolish. The long, sharp needles are twins; a polarized light micrograph* of the same area reveals that each twin is of a different hue and therefore is of different orientation from the remainder of the grain containing it. These pictures are at a larger magnification and the grain size is actually smaller than that of the 98 or 100% hafnium crystal bars of Fig. 2 and 3. (This bar had been grown to the greatest diameter as shown at the bottom of Fig. 1.)

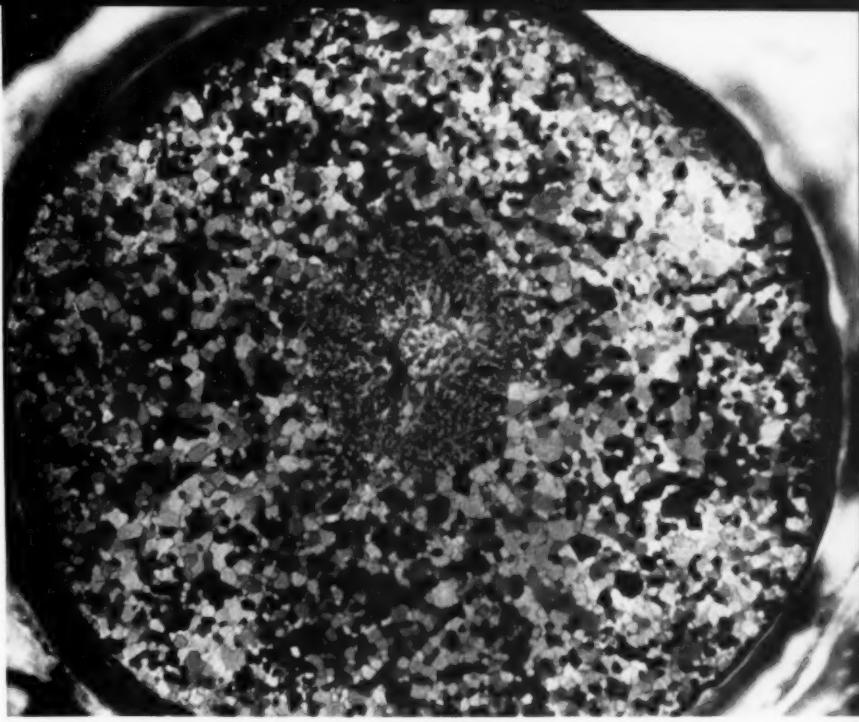
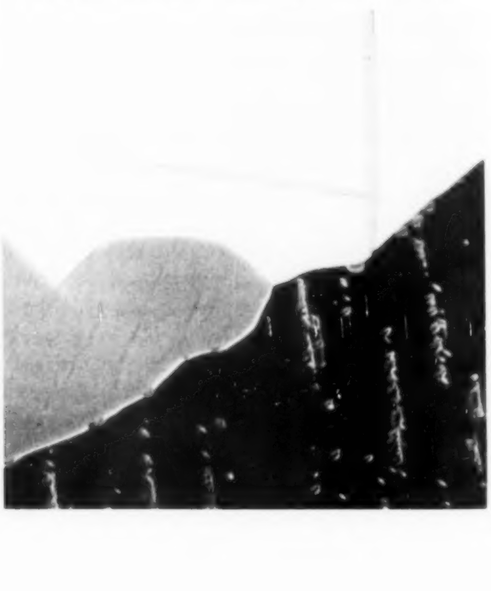


Fig. 6 – Complete Cross Section of 76% Hafnium Wire Showing Effect of Tungsten Core on Recrystallization After Cold Swaging and Annealing at 800° C. for 2 Hr. and Quenching. Polarized light. 100 ×

Figure 4b is also the 76% hafnium alloy and shows the strain effects resulting from cold work intentionally introduced by pressure from pincers used to cut off a portion of the bar. A longitudinal face was polished. This was an extreme end of the piece and includes a large portion of the tip containing the most severely deformed metal. One should visualize pressure applied at right and left of the top.

Figure 5 is an example of the supposedly pure hafnium (Bar A), as received and photographed at 500 × after electropolishing. It is part of the same field seen in Fig. 2b, and shows how clearly each grain is defined by electropolishing. Note also the texture pattern.

Fig. 5 – Structure of Supposedly Pure Hafnium, as Received. Longitudinal section under polarized light. Electropolished. 500 ×



Swaged and Annealed Metal – It was not considered necessary to include photomicrographs of these materials in the worked condition since the structures obtained by annealing at 500° C. (930° F.) show no change (with the exception of the unalloyed zirconium, Bar D, which appeared to display incipient recrystallization).

As noted above, the bars as received were cold swaged to 50% in diameter, and pieces were then annealed 2 hr. at 500, 800 and 1100° C. (930, 1470 and 2010° F., respectively) followed by water quenching. Bar D of pure zirconium was used as control.

Annealing the zirconium at 500° C. revealed incipient recrystallization; 2 hr. at 800° C. caused complete recrystallization and considerable grain growth. The sample annealed at 1100° C. was quite typical of such material when quenched from the beta range.

"Pure" hafnium (Bar A), on the other hand, did not begin to recrystallize upon annealing at 800° C. Although the metal recrystallized

*This (and others in the original contribution) could not be reproduced within the space allotted.

during 2 hr. at 1100° C., slight directional effects still remained, and there was not the amount of grain growth evidenced by the zirconium alloys. In other words (mainly mine), we have not attained entirely relaxed, equiaxed grains at this temperature for this time.

The 98% hafnium, Bar B, after annealing at 500° C. was apparently unchanged from the swaged structure. 800° C. seems to be the borderline temperature for this alloy. A portion of the bar was recrystallized along the entire length and the remainder was not. This effect was checked by heat treating another section and the same results were obtained. There are several small grains forming within the twins. Homogeneity of deformation is questionable. Fully recrystallized metal appears after annealing at 1100° C., although the grain sizes are far from uniform – some are fairly large, some are medium.

Samples of Bar C – nominally 76% hafnium, 24% zirconium – show the effect of the addition of hafnium to zirconium (when compared to the microstructures of Bar D) or vice versa, when compared to Bars A and B. Structure of Bar C after swaging and annealing 2 hr. at 500° C. remained essentially unchanged from the cold worked structure. In this it is similar to hafnium Bars A and B with higher purity; on the other hand, in the "pure" zirconium bar recrystallization had started. As shown in Fig. 6, recrystallization is complete after annealing at 800° C. but the average grain size, even of the outer region, is very much smaller than that attained by zirconium at this temperature. After annealing at 1100° C. Bar C had very large grains. After annealing at this temperature pure hafnium had smallest grains, 98% hafnium somewhat larger grains, and the 76% hafnium had very large grains.

METALLOGRAPHIC PREPARATION

In metallographic processing hafnium responds nicely to the same aceto-perchloric electropolishing described in *Metal Progress* for zirconium (November 1950, p. 709) and titanium (June 1951, p. 816). The prescribed solutions differ only slightly, being 100 to 5 parts by volume of glacial acetic acid to perchloric acid for zirconium and 100 to 6 for titanium. Either is suitable for hafnium.

Similar precautions are used in cutting and preparing hafnium samples since the metal deforms readily and therefore deeply. Emery paper polishing should not be continued through 4/0 paper since a grit finer than 3/0 tends to burnish rather than to remove metal.

One suggestion should be noted in the electropolishing of hafnium as well as zirconium and titanium: Several successive immersions in the fluid, while the current is on, of a few seconds' duration each with continuous agitation, will give a much better polish than a single lengthy immersion with the sample stationary. Polishing takes about 18 volts of direct current, drawing approximately 0.4 amp. for small surface areas such as these hafnium wires, which are 0.080 to about 0.2 in. in diameter.

The general method of metallographic polishing by electrolysis in a chemical bath was first introduced by Jacquet, and mentioned in a letter to the editor of *Nature* for June 29, 1935. The discovery appears to have been a result of intensive examination of copper films deposited in the presence of various colloids. Jacquet stated that copper could be polished by making the sample the anode in an aqueous solution of orthophosphoric acid at high current density. Later in the same year, he presented a paper in *Comptes Rendus* (Dec. 30, 1935) concerning the same procedure but stating that he had found lower current density quite satisfactory for polishing copper.

Many variations of the electrolytic method have since been published, differing mainly in the composition of the electrolyte. Baths containing perchloric acid have been used successfully for aluminum, iron, lead, steel, tin, uranium and vanadium. A similar procedure has given good results for thorium but leaves much to be desired when used on beryllium.

Electropolishing is most satisfactory for hafnium and zirconium and certain of their alloys. For some of the alloys displaying two or more phases, mechanical polishing and chemical etching are more useful. Photomicrographs of hafnium and zirconium and their alloys have been included in several recent publications (see references 9, 10 and 11 on the opposite page).

Another method for sample preparation is the attack-polish originally proposed by Woods for tungsten and later by Metz and Woods for zirconium (references 12 and 13). It consists of adding a common etchant to the abrasive, which is applied to the usual cloth-covered polishing wheel. For zirconium and hafnium the abrasive carrier is a dilute mixture of hydrofluoric acid and water. Any useful etchant for either of these metals would undoubt-

edly contain hydrofluoric acid since it is the only common agent which quickly attacks and brightens them.

Obviously, the addition of hafnium to zirconium raises the recrystallization temperature and also the $\alpha \rightarrow \beta$ transformation temperature. The hafnium content of all material was calculated from specific gravity values, and the results were in good agreement with chemical analyses performed by the Philips Co. Methods for chemical analysis of hafnium are difficult and not always reliable. Differing values have been published for density, lattice parameters, and transformation temperatures of hafnium of supposedly known purity.

There are discrepancies between the results of J. D. Fast and Pol Duwez in their presentations on the transformation of hafnium. Conclusions were drawn from the lattice constants as to the approximate composition of their hafnium samples but the methods used for calculating the lattice parameters apparently were not the same. This means that the metal used by Duwez was probably of higher purity

than Fast indicated. This discrepancy was pointed out by R. B. Russell, who has investigated zirconium and hafnium at Massachusetts Institute of Technology, using the same hafnium and alloys that formed the basis for the present paper.

F. B. Litton reports recrystallization of hafnium occurring between 700 and 800° C. (1300 and 1475° F.). The crystal bar used in his work ranged between 98.92 and 99.17% hafnium, and it was reduced 65% in thickness by cold rolling prior to annealing in argon. The higher recrystallization temperature range found for the hafnium used in the investigation at Massachusetts Institute of Technology would indicate that the metal was actually of higher purity than that used by Litton, if there were no other factors to be considered, such as the degree of cold working introduced. Litton's microstructures confirm the conclusion that hafnium and zirconium form an uninterrupted series of solid solutions.

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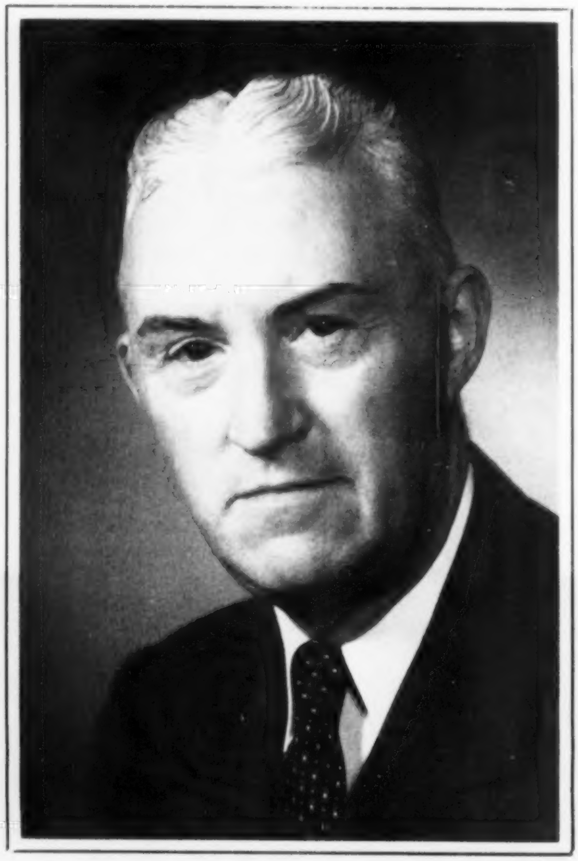
• Eminent Living Metallurgists •



Ralph L. Wilson

President • American Society for Metals • 1952-53

It is not often that a metallurgist creates such a strong and lasting impression during a ten-year period with an industrial concern that he is invited to return after a six-year absence and accept a much more responsible position. Your distinguished National President is one of this small group. This fact is eloquent testimony of the high professional and personal regard which both the management and his associates at the Timken Roller Bearing Co. hold for their director of metallurgy.

Few A.S.M. members who attend their local chapter meetings fail to recognize him on sight, since he has addressed at least one gathering of nearly every chapter over the years. He is an able speaker with a fine delivery and a lucid, interesting approach to the many subjects on which he talks. He is a distinguished-looking man – tall, slender, with a ruddy complexion and striking white hair. His friendly smile and modest manner are well known to his literally hundreds of good friends all over the country who greet him affectionately as "Ralph".

He was born at Uhrichsville, Ohio, on Sept. 19, 1899, and when still a boy moved a few miles north to Canton with his widowed mother. Life was a bit grim for him in those early years, and odd jobs, a paper route and drug-store delivery chores occupied most of his spare time while bolstering the family finances. As his drugstore duties expanded and he became a full-fledged clerk, he acquired a deep interest in chemistry and even thought of studying pharmacy. He was rescued for the metallurgical profession by virtue of summer employment at the United Alloy Steel Co., where the Lehigh alumni on the staff convinced him of the obvious advantages of studying metallurgy. He did his work there under famed Professor Richards and received his degree in electrometallurgy in 1922.

Ralph began his career at United Alloy Steel Co. in the formative days of the alloy steel industry. His technical ability, fine personality and desire to acquire additional knowledge were the prime reasons for his rapid advancement at United, and, after the merger in 1926, at the metallurgical laboratory of the Central Alloy Steel Corp. Here, with Marc Grossmann and his associates, he contributed much to the development of the engineering alloy steels.

He first joined the staff of the Timken steel mill in 1928. One of his early assignments was to follow the research program on steels for high-temperature service just being started by the company at the University of Michigan under the direction of A. E. White and C. L. Clark. His close association with this program over a ten-year period made him a recognized authority on high-temperature metallurgy, and this reputation has gained added luster in the intervening years. One of his outstanding contributions in this field was a large share in the development of the stress-rupture test to evaluate steels for high-temperature service.

Late in 1937, he left Timken for the Climax Molybdenum Co., where he widened his professional experience and greatly enlarged his circle of friends by specializing in foundry applications of moly.

When the war came, he became a part of Operation Washington by joining Herb French's Metallurgical Branch of the War Production Board. Here, with Ernie Hergenroether, Don Reese, Burns George, George Sands and others, he warped the metallurgical destinies of the steel-producing and consuming industries around to fit the ever-changing ferro-alloy supply picture. He became chief of the Constructional Alloy Steel Section, W.P.B., leader on superalloys for the Metallurgical and Operations Committee and a member of the Industry Advisory Committee on Superalloys. Here, also, he developed to a high degree the ability to conduct much of his business by telephone with appropriate gestures of the free hand, and he learned to say "no" – pleasantly, painlessly, softly and firmly. Those who came to bluster, beg or cajole in those days always found in Ralph a good listener, an able negotiator and an astute compromiser.

He rejoined the Timken Co. staff in January 1944 as chief metallurgical engineer, when Walter Hildorf was approaching retirement; Wilson succeeded to his present title in 1946. He is responsible for directing metallurgical activities of all divisions of the company.

To his friends, it is no news that Ralph Wilson is an intellectual with wide interests. He makes an active hobby of gardening and his flower garden is his pride and the envy of his neighbors. He can spout the botanical names of plants, flowers, shrubs and trees until his hearers are dizzy, and enthusiastically discuss the merits of the 18 different varieties of *ilex opaca* (American holly to you) with experts. He has an excellent command of both French and German and is in considerable de-

mand as an interpreter for visitors and a translator of foreign letters and communications. He is both a student of etching technique and a collector of prints, many of which are requested for display by galleries. He is a member of the National Art Institute and the Cleveland Museum of Art. One of his pet projects is the occasional donation of a painting to the art collection of his alma mater. A scurrilous rumor has it that the awkward stance Ralph assumed when his picture was taken on the occasion of one of these presentations was due to the necessity for partial censorship of the donated painting.

His artistic propensities are offset by the fact that he was a member of one of Lehigh's famous wrestling teams and he is still an enthusiastic observer of amateur wrestling, although he has no use for the present denizens of the grunt and groan industry. He is a loyal rooter for the Canton McKinley High School football team and the weather must be bad indeed to prevent his attendance. Ralph gave up golf when he found out the hard way that a new set of clubs was no shortcut to golfing excellence. It was typical of the man that, since he wouldn't take the necessary time to become a good golfer, he gave it up completely rather than be a dub.

Above and beyond all this, there are few members of the profession with as wide and thorough a knowledge of current metallurgical literature. A bachelor, he lives a quiet, well-regimented personal life and spends hours on end in the continued pursuit of knowledge — metallurgical and otherwise.

Your National President, a 25-year member, has an outstanding record of service to A.S.M. He was chairman of the Canton-Massillon Chapter in 1931-1932, national trustee from 1936 to 1938, national treasurer from 1949 to 1951 and vice-president in 1952. He holds memberships in American Society for Testing Materials, American Society of Mechanical Engineers and American Petroleum Institute and has been active in their affairs as well.

It is no accident, therefore, that Ralph L. Wilson was chosen to join the list of eminent metallurgists who have served A.S.M. as president. He is a man of highest integrity, professional ability and, above all, a scholarly gentleman.

Thin Metals That Remain Flat After Machining. . . . .

Extremely close tolerances for flatness and parallelism are often specified in the manufacture of precision instruments. Typical specifications for a thin, intricately shaped part 12 in. long might state, "Must be flat and parallel to within 0.0002 in. per in." Requirements similar to this are a matter of everyday occurrence at the Indianapolis Naval Ordnance Plant. Machining and clamping techniques and stress-relieving treatments are important aids in solving the problem of maintaining flatness. This problem is greatly simplified with some of the wrought aluminum alloys.

According to a theory recently advanced, certain aluminum alloys absorb more internal stresses from a given amount of cold work than do others. By using an alloy which absorbs only a relatively small amount of stresses from cold work, the manufacture of instrument parts to precision tolerances is considerably simplified.

Because of their availability and common usage, the duralumin alloys 17S, and more recently 24S, often have been specified for precision instrument parts where low specific gravity is desired. Almost invariably, except when thick sections are involved, some type of stress-relieving of these alloys is necessary when very close tolerances of flatness and parallelism are required. Such treatments on these alloys, originally in the solution-treated and aged condition, are unsatisfactory for several reasons.

The duralumin alloys become susceptible to

intergranular corrosion when reheated to about 450° F., which is close to temperatures used to stress-relieve them. However, even though these alloys are substantially stress-relieved, they seem to have the property of building up internal stresses relatively rapidly when subjected to further machining, and therefore often require additional stress-relieving. Reheating is also objectionable since physical properties are lowered. If heated high enough to yield a full anneal, they become soft and develop poor machinability. The ideal answer would be to have an alloy which does not have to be stress-relieved but which has physical properties high enough for the application of the part. For these reasons the Indianapolis Naval Ordnance Plant searched for a better wrought aluminum alloy for use in precision instruments.

Attention was directed to alloy 61S-T6 (solution-treated and aged) because it has excellent corrosion resistance after it has been reheated. Stress-relieving experiments were made to determine the thermal cycle which would yield satisfactory physical properties and still relieve internal stresses for all practical purposes. The back-reflection X-ray method was used as a guide, since lack of stresses is indicated by the presence of resolved doublets, while the presence of stresses

Aluminum Alloys for Thin Parts

is indicated by doublets that are diffuse.

It was found that the doublets representing the 61S-T6 were resolved; those of the 17S-T4 and 24S-T4 were diffuse. Resolution treatment of the latter alloys always resulted in resolved doublets. Curiously enough, it was found possible to manufacture many of the 61S-T6 parts to precision tolerances of flatness and parallelism without any stress-relieving treatment, but this was not possible with many of the same parts when the duralumin alloys were used.

One machine shop eliminated the use of the duralumins and changed to 61S-T6. After a two-year period a survey was made of the results. No stress-relieving was used with many items, but it should be noted that parts were not made in production quantities. Sometimes it was necessary to stress-relieve certain parts of very complicated design, and occasionally a sheet of 61S-T6 was used which had behaved poorly in the fabricated part and had to be stress-relieved. Another machine shop decided to stress-relieve the 61S-T6 as a safety measure and reported successful results from a treatment of 450° F. Both shops reported a considerable savings in time and effort in obtaining precision tolerances of flatness and parallelism by eliminating the duralumin alloys and using alloy 61S-T6.

The gear blank shown in Fig. 1 was used in these experiments and tests were made in duplicate. When 17S-T4 was used, the machinist reported he "had to fight it all the way" to keep it flat. Samples of 61S-T6 were also tried and results were somewhat better. Two weeks later the gear blanks were again measured for flatness and were found to have gone out of tolerance during this

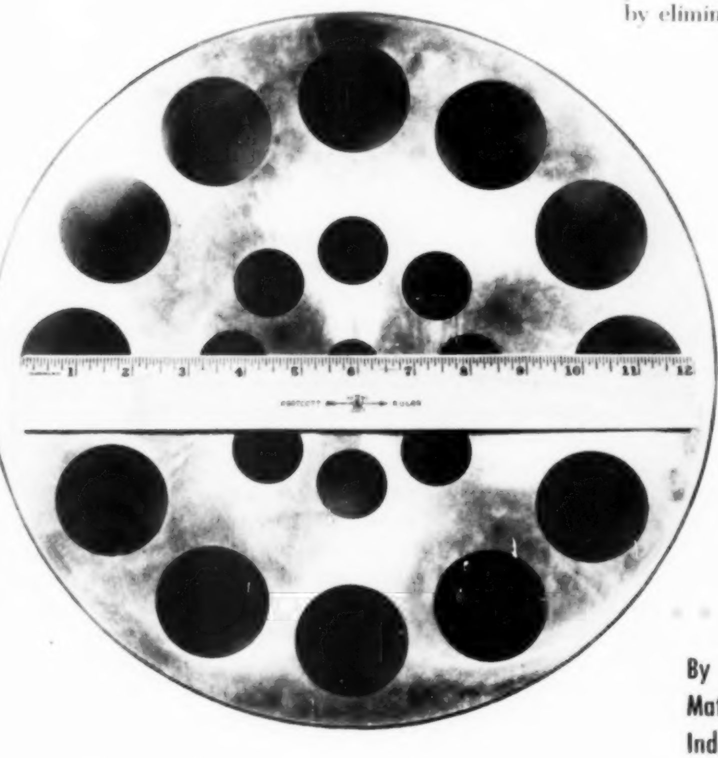


Fig. 1 – Gear Blank (Partially Machined) Requiring Such a Degree of Flatness That Concentricity of Bore and Pitch Diameter Must Be Held Within 0.0005 In. Maximum Indicator Reading

By JOHN C. WAGNER, Head, Metallurgical Branch Materials Division, Research and Test Department Indianapolis Naval Ordnance Plant, Indianapolis

period, even though they had been stored on a surface plate. It was then learned that the 61S-T6 used was slightly warped when received and had been straightened in a press prior to machining. The experiment was repeated using 61S-T6 which required no straightening. This time no trouble was encountered. Stress-relieving was not used in the experiments with 61S-T6; the 17S-T4 was heated to 400° F. for 1 hr. and then air cooled.

The following idea might be used to explain some of these facts: The resolution treatment of 17S-T4 removed enough of the stresses so that the doublets on the X-ray films became resolved. The unresolved doublets associated with the as-received material are believed to be due to internal stresses put into the material during a straightening operation at the mill. Alloy 61S-T6 is likewise straightened, but the doublets remain resolved. The difference here is believed by the writer to be due to less inherent susceptibility of 61S-T6 to absorb internal stresses.

The duralumin alloys are basically different from 61S, since the former depend on copper aluminide to impart high physical properties after heat treatment. Alloy 61S contains almost no copper and is of the magnesium silicide type. On this basis, 53S and 63S would be expected to behave like 61S in experiments similar to the above. The alloy 75S, although somewhat different from the duralumins, does contain considerable copper and would be expected to behave like 17S-T4 and 24S-T4 if the theory is reasonably correct.

A few preliminary experiments were made to check this theory. X-ray diffraction pictures were taken and results are as follows: 53S-T6 and 63S-T6 yield resolved doublets, while 75S-T6 gives diffuse doublets. (See Fig. 2.) The doublets of 63S-T6 are more resolved than those of 53S-T6 and 61S-T6. These facts are in agreement with the theory; however, the theory provides no explanation for the superior resolution of the 63S-T6 doublets.

Although it has not been possible to perform extensive stability tests on 53S and 63S as of this writing, the following information has been obtained: Alloy 75S-T6 is definitely difficult to hold to precision tolerances of flatness and parallelism. The following single experiment was performed using 53S-T6, 61S-T6, and 24S-T4 which had been resolution treated and

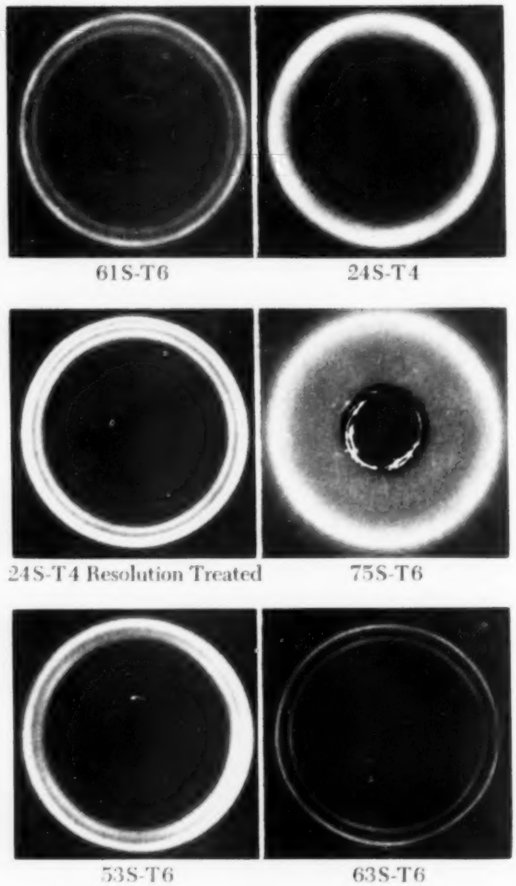


Fig. 2 – X-Ray Diffraction Pictures of Magnesium-Silicide-Type Aluminum Alloys Show Resolved Doublet; Copper-Aluminide-Type Alloys Show Diffuse Doublet. Copper radiation, 5 cm. specimen-to-film

aged 8 hr. at 350° F. Samples were made from $\frac{3}{16}$-in. stock, 5 in. long and 2 in. wide. They were then fly-cut at a rapid speed to a thickness of 0.115 in. (±0.003 in.) and measured for flatness. The 61S and 53S plates were found to be more nearly flat and parallel than the 24S. This is an indication that 53S-T6 is comparable with 61S-T6 in this respect, but much more data should be accumulated before definite conclusions are drawn. No stability data are available for 63S-T6.

For the several reasons already discussed, the writer believes that 61S-T6 inherently absorbs fewer stresses under a given amount of cold work than do the solution-treated and aged duralumin alloys, as well as 75S-T6. It also appears likely that 53S-T6 and 63S-T6 compare favorably with 61S-T6 in this superior ability to "stay put".

Short Runs

Pickle Liquor Recovery

Disposing of the more than 600 million gal. of pickle liquor each year in the steel industry has been a difficult and costly problem for many years. The problem arises from the fact that spent liquor cannot be emptied into streams and lakes as sewage without first being treated to prevent pollution, yet processes for such treatment are either exceedingly expensive or result in other byproducts which pose equally serious disposal problems.

A new recovery process for spent pickle liquor developed by the Chemical Plants Div., Blaw-Knox Co., Pittsburgh, is said to overcome these difficulties. The Blaw-Knox-Ruthner process (with recognition to Othmar Ruthner who invented it) recovers the entire sulphate equivalent of the spent liquor as re-usable sulphuric acid without using contact or chamber sulphuric acid plants, and the iron is recovered as iron oxide.

Details of the process, the facilities for which would cost about $500,000 for a steel plant using 10,000 tons of sulphuric acid per year, are described as follows: Waste pickle liquor is first concentrated by evaporation and the ferrous sulphate is then converted to ferrous chloride by adsorption of hydrogen chloride. The precipitated ferrous chloride is centrifuged from the mother liquor, the regenerated sulphuric acid being returned without further processing to the pickling line. By roasting the ferrous chloride to produce hydrogen chloride for recycling to the process, a disposable product is obtained in the resulting iron oxide.

Abrasive-Belt Grinding

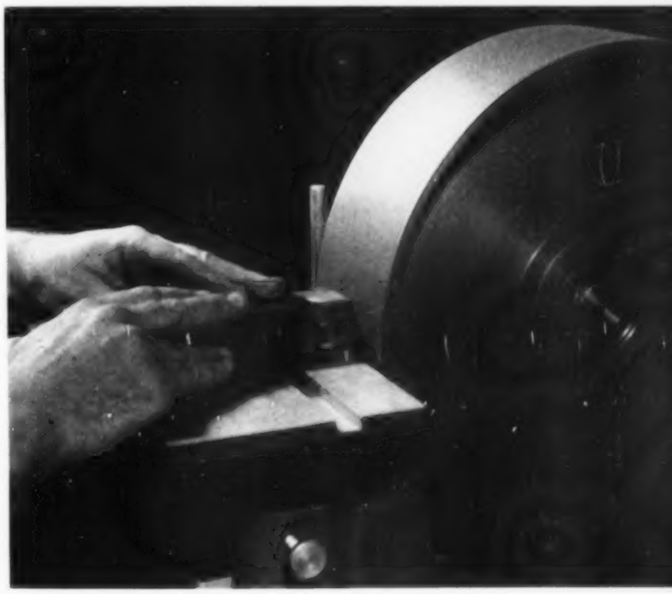
Especially timely because of the current shortage in the supply of industrial diamonds is the method for sharpening tungsten carbide tools recently devised by Behr-Manning Corp., Troy, N. Y., and Fenlind Engineering Co., Rockford, Ill.

In this method sharpening is done by a waterproof paper belt impregnated with silicon carbide called "Speed-Wet Durite" on a 14-in. contact wheel driven by the belt. The advantages of lower operating cost and better cutting edge (as compared with the conventional diamond wheel procedure) claimed for this method result from the two-third reduction in cost of materials, the elimination of the intermediate grind and the finish-honing operation, and a comparatively finer finish which gives a longer tool life. A finish of 2 to 16 micro-in. rms. is produced on the tool surface by the 220-grit belt.

The relief angle is set by adjusting the height of the table until the face of the cutting tool contacts the belt on the periphery of the contact wheel at a point on its curvature that corresponds to the relief angle desired, as set on a vertical gage, mounted near the table at the left of the wheel.

The procedure for sharpening carbide-tipped tools involves two steps: First, rough-grind the clearance angle with a silicon carbide grinding wheel. Second, with the table of the Fenlind belt machine set to produce the correct relief angle, finish both front and side relief angles of the tool, and the nose angle by swinging the tool through approximately a 90° arc. Light manual pressure is adequate to produce a fine finish in 2 or 3 sec.

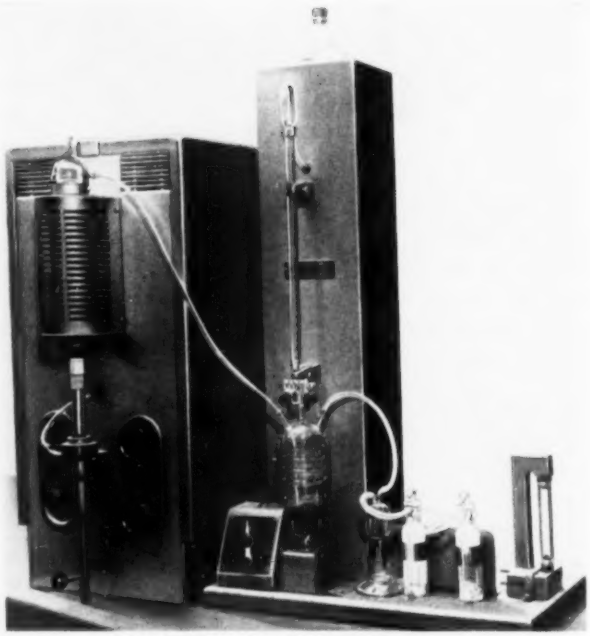
Desired Relief Angle Is Obtained by Adjusting Table Height Until Point of the Tool Reaches the Angle Marked on Calibrated Post at Left of Wheel. Light pressure and a 2 to 3-sec. grind produces the required cutting edge



Laboratory Apparatus

According to Lindberg Engineering Co., Chicago, carbon and sulphur content in ferrous alloys can be determined in 10 min. by means of a simplified procedure which uses the combustion products from a single sample for both determinations. The procedure and design of apparatus are the joint effort of A. C. Holler of Twin City Testing & Engineering Laboratory, W. K. Aites of Westinghouse Air Brake Co., and Lindberg Engineering Co.

The apparatus required for this procedure consists of only three major units: a Lindberg high-frequency induction furnace, burrette for SO_2 titrations, and the three-bulb purifying and absorption train for CO_2. Thorough combustion of samples is assured by the induction heating unit which develops temperatures above 3000° F. Combustion products flow, first, to the burrette for sulphur determinations where the SO_2 is absorbed, then remaining products pass to the two bulbs for purification and finally to the absorption bulb for gravimetric determination as CO_2. The time saving is 22 to 25 min. per determination.



Apparatus for Carbon and Sulphur Determinations Using the Combustion Products of a Single Sample

Fig. 3 — Operator Rolling Flat Stock on Combination Flat and Wire Rolling Mill

Rolling

Small rolling mills for laboratory use and short-run production are available with such "heavy" equipment design features as housings cast of Meehanite type GM alloy to withstand extreme stresses and shock loads, bronze bearings enclosed within a heavy-duty welded steel base, and roller bearings which can be water cooled. These mills, with either 3 or 4-in. diameter rolls, are made by Stanat Mfg. Co., Long Island, N. Y.

The close adjustments possible with the mills permit the production of material to fine tolerances. Parallelism is maintained by hardened and ground screws which can be adjusted individually, or by a single screwdown. The third type of adjustment uses a worm gear screwdown for making fine adjustments while the machine is in operation.

Rolls are of alloy toolsteel hardened and ground to a high finish, or in the unhardened state so that designs can be engraved for the production of patterned surfaces. Special rolls are available for hot rolling, tube compacting or wire rolling. Since the upper rolls are driven from the lower rolls through helical gears, the possibility of marring fine finishes is minimized. The mills are being used to make small machine parts, electronic wire and optical parts.

Standard Stainless Steels, Wrought and Cast

Wrought Stainless Steels *(a)*
(American Iron and Steel Institute Designations; August 1952)

Type No.	Carbon	Chromium	Nickel	Other Elements *(b)*	S.A.E. No. *(c)*
301	0.08-0.20	16.0-18.0	6.0- 8.0		30301
302	0.08-0.20	17.0-19.0	8.0-10.0		30302
302B	0.08-0.20	17.0-19.0	8.0-10.0	Si 2.00-3.00	
303	0.15 max.	17.0-19.0	8.0-10.0	P or S or Se 0.07 min. Mo or Zr 0.60 max.	30303F
304	0.08 max.	18.0-20.0	8.0-11.0		30304
304L	0.03 max.	18.0-20.0	8.0-11.0		
305	0.12 max.	17.0-19.0	10.0-13.0		30305
308	0.08 max.	19.0-21.0	10.0-12.0		
309	0.20 max.	22.0-24.0	12.0-15.0		30309
309S	0.08 max.	22.0-24.0	12.0-15.0		
310	0.25 max.	24.0-26.0	19.0-22.0	Si 1.50 max.	30310
310S	0.08 max.	24.0-26.0	19.0-22.0		
314	0.25 max.	23.0-26.0	19.0-22.0	Si 1.50-3.00	
316	0.10 max.	16.0-18.0	10.0-14.0	Mo 2.00-3.00	30316
TS316	0.10 max.	16.0-18.0	10.0-14.0	Mo 1.75-2.50	
316L	0.03 max.	16.0-18.0	10.0-14.0	Mo 1.75-2.50	
317	0.10 max.	18.0-20.0	11.0-14.0	Mo 3.00-4.00	30317
321	0.08 max.	17.0-19.0	8.0-11.0	Ti is 5 × C (min.)	30321
322*	0.12 max.	16.0-18.0	6.0- 8.0	Ti 1.00; Al 1.00	
325‡	0.25 max.	7.0-10.0	19.0-23.0	Cu 1.00-1.50	30325
347	0.08 max.	17.0-19.0	9.0-12.0	Cb is 10 × C (min.)	30347
TS347	0.08 max.	17.0-19.0	9.0-12.0	Cb is 8 × C (min.)	
TS347A	0.08 max.	17.0-19.0	9.0-12.0	Cb + Ta 8 × C (min.)	
403†	0.15 max.	11.5-13.0		Si 0.50 max.	
405	0.08 max.	11.5-13.5		Al 0.10-0.30	
410	0.15 max.	11.5-13.5			51410
414	0.15 max.	11.5-13.5	1.25-2.50		51414
416	0.15 max.	12.0-14.0		Same as Type 303	51416F
418‡	0.15 max.	12.0-14.0			
420	Over 0.15	12.0-14.0			51420
420F‡	0.30-0.40	12.0-14.0		Same as Type 303	51420F
430	0.12 max.	14.0-18.0			51430
430F	0.12 max.	14.0-18.0		Same as Type 303	51430F
431	0.20 max.	15.0-17.0	1.25-2.50		51431
440A	0.60-0.75	16.0-18.0		Mo 0.75 max.	51440A
440B	0.75-0.95	16.0-18.0		Mo 0.75 max.	51440B
440C	0.95-1.20	16.0-18.0		Mo 0.75 max.	51440C
440F‡	0.95-1.20	16.0-18.0		*(d)*	51440F
442‡	0.20 max.	18.0-23.0			51442
443‡	0.20 max.	18.0-23.0	0.50 max.	Cu 0.90-1.25, Si 0.75 max.	
446	0.35 max.	23.0-27.0		N_2 0.25 max.	51446
501	Over 0.10	4.0- 6.0			51501
502	0.10 max.	4.0- 6.0			

Cast Stainless Steels *(e)*
(Alloy Casting Institute Designations; 1951)

Type No. *(f)*	Carbon	Silicon (Max.)	Chromium	Nickel	Other Elements *(g)*
CA-15	0.15 max.	1.50	11.5-14.0	1.0 max.	*(i)*
CA-40	0.20-0.40	1.50	11.5-14.0	1.0 max.	*(i)*
CB-30	0.30 max.	1.00	18.0-22.0	2.0 max.	
CC-50	0.50 max.	1.00	26.0-30.0	4.0 max.	
CE-30	0.30 max.	2.00	26.0-30.0	8.0-11.0	
CF-8	0.08 max.	2.00	18.0-21.0	8.0-11.0	
CF-8C	0.08 max.	2.00	18.0-21.0	9.0-12.0	Cb or Cb + Ta *(h)*
CF-8M	0.08 max.	1.50	18.0-21.0	9.0-12.0	Mo 2.0-3.0
CF-12M	0.12 max.	1.50	18.0-21.0	9.0-12.0	Mo 2.0-3.0
CF-16F	0.16 max.	2.00	18.0-21.0	9.0-12.0	Mo 1.5 max. P 0.17 max. Se 0.20-0.35
CF-16Fa	0.16 max.	2.00	18.0-21.0	9.0-12.0	Mo 0.40-0.80 S 0.20-0.40
CF-20	0.20 max.	2.00	18.0-21.0	8.0-11.0	
CH-20	0.20 max.	2.00	22.0-26.0	12.0-15.0	
CK-20	0.20 max.	2.00	23.0-27.0	19.0-22.0	
CN-7MCu	0.07 max.	*(j)*	18.0-22.0	21.0-31.0	Mo; Cu *(j)*
HC	0.50 max.	2.00	26.0-30.0	4.0 max.	*(i)*
HD	0.50 max.	2.00	26.0-30.0	4.0- 7.0	*(i)*
HE	0.20-0.50	2.00	26.0-30.0	8.0-11.0	*(i)*
HF	0.20-0.40	2.00	18.0-23.0	8.0-12.0	*(i)*
HH	0.20-0.50	2.00	24.0-28.0	11.0-14.0	N 0.2 max. *(i)*
HI	0.20-0.50	2.00	26.0-30.0	14.0-18.0	*(i)*
HK	0.20-0.60	3.00	24.0-28.0	18.0-22.0	*(i)*
HL	0.20-0.60	3.00	28.0-32.0	18.0-22.0	*(i)*
HT	0.35-0.75	2.50	13.0-17.0	33.0-37.0	*(i)*
HU	0.35-0.75	2.50	17.0-21.0	37.0-41.0	*(i)*
HW	0.35-0.75	2.50	10.0-14.0	58.0-62.0	*(i)*
HX	0.35-0.75	2.50	15.0-19.0	64.0-68.0	*(i)*

*Not an A.I.S.I. standard; also known as "stainless W".
†Turbine quality. ‡Not an A.I.S.I. standard.

Notes on Wrought Steels

(a) All composition ranges are based on ladle analysis. Standard permissible variations from specified chemical ranges or limits for check analysis are shown in Section 24, Steel Products Manual.

(b) **Manganese:** 2.00 max. in all 300 types except S.A.E. 30325 which has 0.60 to 0.90, and S.A.E. 30347 which has 2.50 max.; 1.00 max. in all 400 and 500 types except 416 (1.25 max.), 430F (1.25 max.) and 446 (1.50 max.). Manganese in S.A.E. 51420F and 51440F is 1.25 max. **Silicon:** 1.00 max. in all types except 302B (2.00 to 3.00), 310 and 310S (1.50 max.), 314 (1.5 to 3.0), and 403 (0.50 max.). Silicon in S.A.E. 30321 and 30347 is 1.50 max. and in 30325 is 1.00 to 2.00. **Phosphorus** is 0.045 max. in all the 300 series except 303, and 0.040 max. in all other types except 416 and 430F. **Sulphur** is 0.030 max. in all types except 303, 416, 430F, in each of which it is 0.07% min. if added for improving machinability.

(c) S.A.E. composition limits as of January 1952 may be slightly different from the A.I.S.I. analyses quoted.

(d) Same as in 51416F except that Mn or Zr is 0.75 max.

Notes on Cast Steels

(e) Most of these are also covered by A.S.T.M. specifications A296-49T and A297-49T.

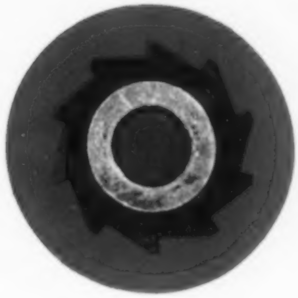
(f) Designations with the initial letter C indicate alloys generally used to resist corrosive attack at temperatures less than 1200° F. Designations with the initial letter H indicate alloys generally used under conditions where the metal temperature is in excess of 1200° F.

(g) **Manganese:** 1.00 max. in CA-15, CA-40, CB-30 and CC-50; 1.50 max. in all other C alloys; 1.00 max. in HC; 1.50 max. in HD; 2.00 max. in all other H alloys. **Phosphorus** and **sulphur:** each 0.04 max. in all alloys except CF-16F, wherein P is 0.17 max., and in CF-16Fa, wherein S is 0.20 to 0.40.

(h) Columbium 8 × C min., 1.00% max.; Cb + Ta 10 × C min., 1.35 max.

(i) Molybdenum 0.5 max. (not intentionally added).

(j) Proprietary alloys contain varying amounts of Si, Mo and Cu.



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Commercial Controls Corporation liquid carburizes clutch sleeves, combs, feed ratchets, gear assemblies and locking bails for its JUSTOWRITER Automatic Justifying Composing Machine in AEROCARB E & W.

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For example, the locking bail made of C 1010 steel with pins of B 1113 steel is carburized in AEROCARB E & W salt baths at 1400°F for five minutes and oil quenched. Maximum case of .001 inch is specified to give desired stiffening to this part.

The other extreme is the feed ratchet, also of B 1113 steel, carburized in AEROCARB E & W at 1650°F for 60 minutes to give a case depth of .015 - .020 inches. Ratchets, which must have good impact strength, are then air-cooled, and teeth are induction hardened to 72 Rockwell 45N minimum, leaving hubs soft at about 90 Rockwell B.

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Structures and Properties of Some Carbo-Nitrided Cases

USE OF CARBO-NITRIDING as a method of case hardening steel has increased considerably during the past few years, due in part to the relative economy of operation and cleanliness of the treated parts. Considerable data are available concerning the effects of gas composition, carbon absorption, nitrogen absorption and treatment temperature and time on the hardness and microconstituents of the case. There is little information available, however, on the fatigue properties of finished parts.

In order to obtain some of this missing information, test bars were made from several grades of steel. These were then heat treated by two outside companies using four different practices of carbo-nitriding. Bending load properties, impact fatigue properties, microhardness of case, and microstructure were then determined.

Details concerning the four treatments are listed in Table I. It will be noted that a considerable variation in atmospheres and cooling rate is represented, but the case depths were about the same. For comparison, identical tests were also run on bars hardened in liquid cyanide. (See the last line in Table I.)

Steels tested were C1024, 4028, 4620, 5120, TS8120, TS81B20 (from a boron-treated ingot of the preceding heat), 8620 and 9415.

Since conventional design and manufacturing

By K. B. VALENTINE, Project Engineer
Pontiac Motor Division, General Motors Corp.

Table I – Carbo-Nitriding Practices

CODE	GAS MIXTURE CU. FT. PER HR.	MAXIMUM FURNACE TEMPERATURE	COOLING METHOD	CASE DEPTH
A	Ammonia, 350 Natural gas, 76 Carrier gas, 400	1580° F.	Cooled in furnace to 1225° F. then slowly cooled in vestibule to 200° F. with atmosphere surrounding parts.	0.015 in.
B	Ammonia, 350 Propane, 110 Carrier gas, 1500	1550	Quenched directly into oil at 130° F.	0.010
C	Ammonia, 350 Propane, 110 Carrier gas, 1500	1550	Cooled in furnace to 1080° F. and quenched into oil at 130° F.	0.010
D	Ammonia, 350 Propane, 110 Carrier gas, 1500	1550	Blasted with carbo-nitriding gas.	0.013
E (Liquid cyanide)	Bath Composition: 33% NaCN 1.3% NaOH 65.7% $NaCO_3$	1550	Quenched directly into oil at 130° F.	0.006

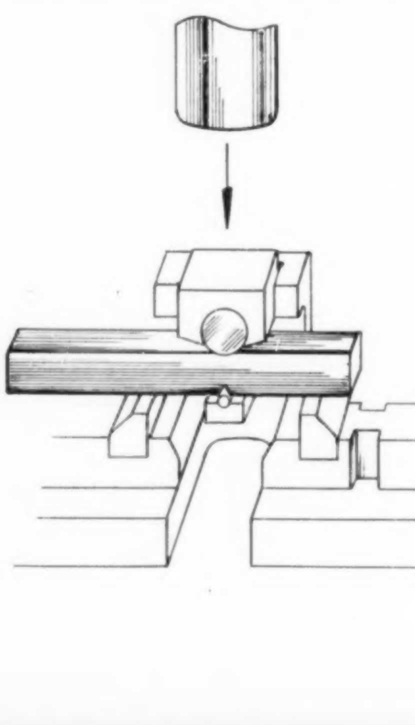
methods cannot eliminate stress-raisers such as notches or fillets, we wanted to determine the effect of the heat treatments listed in Table I on notched bars. For this purpose, two series of tests were run utilizing standard Izod specimens whose notches were coined to avoid tool marks. All notches were inspected at 45× both before and after heat treatment to eliminate test bars with burs, cracks or scratches. In one series, the bars were subjected to increasing loads in bending until they cracked at the notch. In the other series, they were subjected to a cyclic impact load until fatigue failure occurred at the notch.

Bending Test – Subsequent to heat treatment, certain test bars were subjected to static bending stresses. The load was applied through a ⅜-in. roller directly over the notch, as shown in Fig. 1. Supports were placed 1¼ in. apart. The holding fixture contained suitable guides and stops to assure proper positioning and alignment. The notch was examined for cracks at 45× after each 500-lb. increment of load.

Results are listed in Table II. These indicate three types of failure: (X) brittle failure wherein cracking started in the case before the bar acquired any permanent set; (Y) a completely brittle failure wherein the specimen broke clear through case and core; and (Z) ductile failure wherein cracking occurred only in the case and after the bar had acquired some degree of permanent set – on the order of 0.003 to 0.005 in. bend at the center.

Impact fatigue tests were also run using Izod impact bars. For this purpose, a machine was built which dropped a 3-lb. weight 1 in. on a ¼-in. roller directly over the notch as illustrated in Fig. 2. The weight was raised by the cam and fell on the anvil by gravity. The anvil kept the roller positioned directly over the notch and suitable guides correctly located the bar at all times. Supports for the test bar were again at equal distances from notch – ⅝ in. The machine ran at 8400 cycles per hr. and was

Fig. 1 – Fixture for Bend Test. Pin fits loosely in notch to insure proper location immediately under application of load. Supports on 1¼-in. span. Dimension of case hardened test piece: 10 x 10 x 75 mm. (0.394 x 0.394 x 2.952 in.) Standard Izod notch, coined prior to heat treatment to eliminate tool marks



equipped with an electric timer. An automatic shut-off switch was activated by a slight increase in deflection which denoted that failure had started.

Results of the impact fatigue tests are also listed in Table II. These tests indicate the following properties:

1. Superior impact fatigue life of cyanided and oil quenched test bars (Treatment E) as compared to the carbo-nitrided bars, regardless of cooling method.

2. Superior impact fatigue durability of carbo-nitrided test bars of 1024 steel direct quenched in oil (Treatment B) as compared with the other methods of cooling that were tested.

Table II – Slow Bend and Impact Fatigue on Notched Bars
(Figures are averages of two to four tests)

Steel	Treatment	Core Hardness	Slow Bend		Impact Fatigue‡	
			Load	Failure†	High	Low
1024	A	B-90	2000 lb.	X	8,400	7,600
1024	B	C-43	4700	Y	29,400	22,700
1024	B*	C-34	4000	Z		
1024	C	B-94	2500	Z	20,000	11,000
1024	D	B-98	3000	Z	12,600	12,600
1024	E	C-42	4500	Y	97,400	51,200
1024	E*	C-35	3000	Z		
4028	B	C-45	3400	Y	14,300	9,200
4620	B	C-42	4500	Z	17,600	14,300
4620	E*	C-34	4000	Z	33,600	27,906
5120	B	C-35	4000	Z	25,200	22,000
5120	E	C-34	—	—	35,300	32,800
TS8120	B	C-38	4000	Z	22,700	19,400
TS81B20	B	C-44	4700	Y	16,800	15,100
8620	B	C-47	5500	Y	18,500	18,500
8620	E*	C-38	4500	Z		
9415	B	C-45	3500	Y	19,300	17,000

*Plus a draw at 800° F. ‡Cycles to failure
†X is crack without permanent set
Y is brittle failure
Z is slight permanent set prior to crack

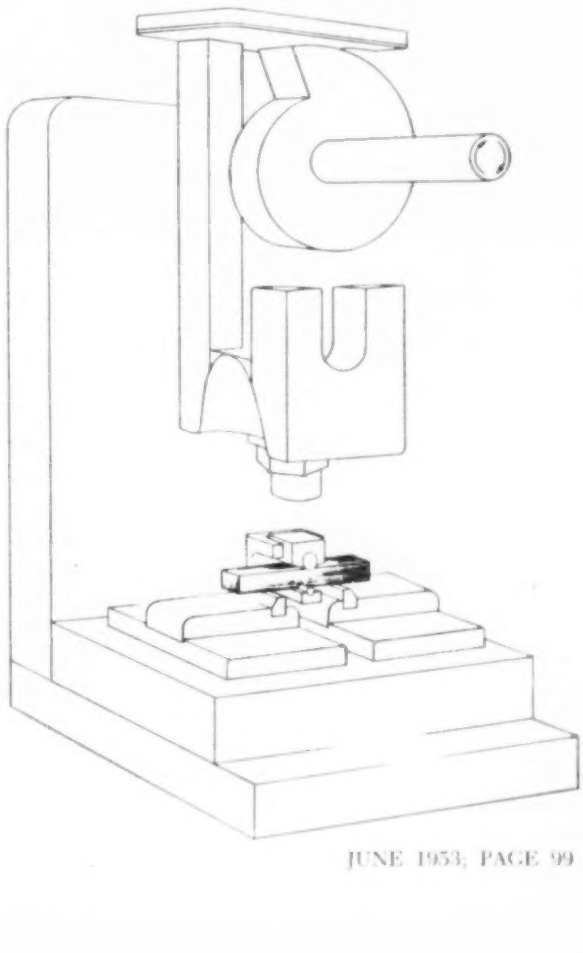
Toughness of Case – The susceptibility of a hardened case toward cracking and exfoliation should be regarded as an important engineering property. (Cracking in service can result from repeated loads during normal operation.) To compare the ability of the various hardened cases to withstand forces that promote cracking and exfoliation, flat test specimens were subjected to repeated impacts with a weighted ball.

The machine shown in Fig. 2, with some modifications, was used. A 10-mm. tungsten carbide Brinell ball attached to a 4-lb. weight was lifted 3¾ in. above the test surface by the cam, and dropped. Test bars were of 1024 steel, ⅜ in. thick, ¾ in. wide and 3 in. long, surface ground prior to heat treatment. Each specimen was clamped rigidly to the base of the machine so that repeated impacts were obtained at one spot. Operation was at 8400 cycles per hr. Test bars were first examined after 63,000 cycles; if no cracks were observed, the test was continued and examinations made at about 100,000-cycle intervals. Results are listed in Table III.

Photographs at 14× illustrating typical appearance of impacted areas are shown in Fig. 3. Cracking and exfoliation of the case are clearly discernible in one, and no cracking is noted in the other.

Hardness of Case – Superficial hardness tests using a Vickers indenter loaded at 1000 g. on a Tukon machine were taken at the surface and at 0.002-in. increments below the surface

Fig. 2 – Arrangement for Testing Izod Notched Bar in Impact Fatigue. Three-pound weight was dropped 1 in.; 8400 cycles per hr.



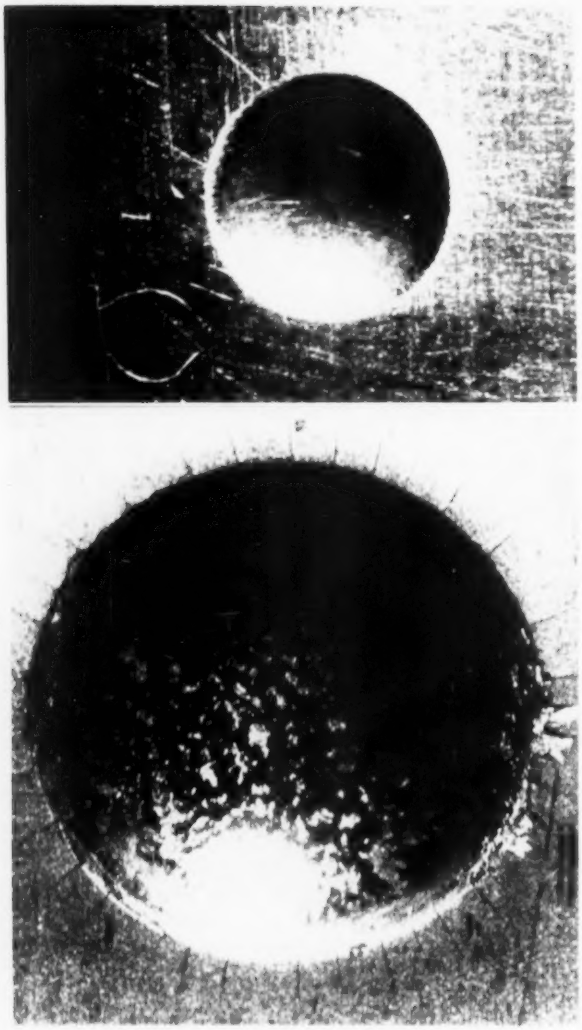


Fig. 3 – 10-Mm. Ball Impression in Carbo-Nitrided Cases After Repeated Impacts of 4 Lb. Dropped 3¾ In. Above: oil quenched case (Treatment B) after one million impacts. Below: cracks in slowly cooled case (Treatment A) after 63,000 impacts

Table III – Weighted Ball Impact Fatigue of 1024 Steel

Treatment	Condition of Case	
	After 63,000 Cycles	After 1,000,000 Cycles
A	Cracked	–
B	No Cracks	No Cracks
B + 800° F. draw	No Cracks	No Cracks
C	Cracked	–
C + 400° F. draw	Cracked	–
C + 800° F. draw	Cracked	–
D	Cracked	–
E	No Cracks	No Cracks
E + 800° F. draw	No Cracks	No Cracks

on sections from the Izod impact bars. Results listed in Table IV agree generally with previously published data. It will be noted that:

1. The cyanide case (Treatment E) had a higher surface hardness than the carbo-nitrided cases tested.

2. A soft layer (as measured by penetration methods) formed at the surface of all carbo-nitrided cases.

3. Quenching directly from the carbo-nitriding temperature into oil (Treatment B) resulted in a harder surface than cooling by the other methods tested.

4. The case produced by liquid cyanide resists change during tempering better than the carbo-nitrided cases tested.

Vickers superficial hardness tests were also run on the alloy steels carbo-nitrided at 1550° F. and oil quenched (Treatment B). Results of these tests are listed in the lower part of Table IV. It will be noted that:

1. Variations in chemical analysis affected the hardness resulting from this treatment.

2. Boron decreased the case hardness.

Examination of the case of S.A.E. 1024 specimens revealed some microstructures similar to those reported by other investigators. (Specimens were chromium plated to prevent rounding of the edges during polishing.)

Considerable differences resulted from the four different practices. The most revealing are illustrated by the unetched photomicrographs (Fig. 4), which show dark, irregular spots near the surface of all carbo-nitrided cases. Of the quenched samples, the piece oil quenched from 1550° F. (Treatment B) contained the least of this dark microconstituent. No similar phase is seen at the surface of the cyanide hardened specimen – note its smooth demarcation from the protective plating.

The alloy steels showed a similar dark phase in the unetched condition, except 4620 and 8620. Considerable difference in microstructure at the surface was also noted between each of the alloy steels given the same carbo-nitriding treatment.

DISCUSSION OF RESULTS

Carbo-nitriding, although not new, is still in its infancy. As often happens, the art preceded an understanding of the basic principles. Consequently, the process is burdened with some conflicting opinions. Some metallurgists recommend that carbo-nitriding can be substituted for carburizing or cyaniding, and that desirable properties are obtained by utilizing

the low critical hardening temperature of a carbo-nitrided case. If this is so, parts should be cooled slowly to below the critical temperature of the core prior to quenching.

In our opinion, the best combination of physical properties for toughness and fatigue strength does not result from a hard case and an annealed core. Fatigue tests reported for carburized parts as well as the present tests show that a *quenched* core of 0.20% carbon steel gives better endurance. Some of the fatigue data presented in Table II are rearranged in Table V to emphasize the necessity of a quenched core for high fatigue properties.

Perhaps where the applied stresses are of low magnitude, carbo-nitriding can be substituted for cyaniding. However, the results of our tests indicate that a considerable difference exists between the fatigue strength of carbo-nitrided and of cyanided test bars (notched). Residual stresses, strength of material, and condition of material at the surface are some of the important factors affecting the endurance limit of a part.

The lower endurance of the carbo-nitrided test bars as compared to cyanided can be partially explained by the microstructure (Fig. 4). The dark, irregular spots in the carbo-nitrided cases have the appearance of a graphitic phase or of voids which could have been produced by polishing. It is interesting to speculate on their nature; their probable effect can more easily be predicted.

It is known that nitrogen increases the solubility of carbon in austenite. Chemical analysis of the outside 0.001 in. of the test bar given Treatment A showed 2.88% carbon. It is also known that nitrogen in large amounts is unstable in steel at temperatures above about 1000° F. Furthermore, Rengstorff, Bever and Floe in their articles in *Metal Progress* for November 1949 and in ⚙ *Transactions* for 1951 noted some difficulty in their investigations in retaining the nitrogen at the surface of carbo-nitrided test bars.

These two facts concerning the behavior of nitrogen may have a decisive effect on the microconstituents resulting from carbo-nitriding.

Treatment A

Cyanided – Treatment E

Fig. 4 – Unetched Structures of S.A.E. 1024 Carbo-Nitrided by Four Different Practices. Cyanided comparison sample at right. Note dark, irregular spots near surface. 500 ×. (All micrographs by Ralph McGau of the metallurgical dept., Pontiac Motor Div.)

Treatment B

Treatment C

Treatment D

Table IV – Vickers Superficial Hardness Tests on Carbo-Nitrided Cases

Steel	Heat Treatment	Hardness at Indicated Depth					
		Surface	0.002 In.	0.004 In.	0.006 In.	0.008 In.	0.010 In.
1024	A	370	500	410	–	–	–
1024	A + 800° F. draw	355	440	360	–	–	–
1024	B	440	540	900	900	730	–
1024	B + 500° F. draw	420	500	630	640	620	–
1024	B + 800° F. draw	480	490	620	570	560	–
1024	C	330	490	360	270	200	–
1024	C + 800° F. draw	455	420	360	300	200	–
1024	D	305	420	580	680	580	–
1024	D + 400° F. draw	330	430	570	570	580	–
1024	E	755	740	740	–	–	–
1024	E + 800° F. draw	605	560	470	–	–	–
4028	B	780	725	620	530	495	480
4620	B	700	635	635	635	580	495
5120	B	500	530	645	600	490	495
TS8120	B	750	645	600	560	550	450
TS81B20	B	645	560	550	465	410	395
8620	B	740	635	540	530	500	495
9415	B	640	540	510	565	510	460

A gradual lowering of temperature or a change in iron-gas equilibrium condition (as during quenching) could release nitrogen, resulting in a supersaturated solution of carbon in iron and the subsequent precipitation of graphite. High carbon content in the surface layer and the appearance of the dark, irregular microconstituents near the surface substantiate this hypothesis. Carbo-nitrided parts did not harden file hard on reheating in neutral salts at 1550° F. and quenching in oil, and the amount of dark microconstituent increased as a result of this treatment. These factors also indicate that an unstable condition may exist in a carbo-nitrided case during cycles of either heating or cooling.

By comparing the micros in Fig. 4 of Treatment B (oil quenched from 1550° F.) and Treatment D (atmosphere blast quench from 1550° F.) it will be noted that the slower cooling rate considerably increased the amount of this dark constituent.

Table V – Fatigue Tests on Notched Bars

Heat Treatment	Core Hardness	Cycles to Failure
A – Furnace cooled to 1225° F. then slowly cooled in vestibule	B-90	7,600
B – Quenched directly in oil from 1550° F.	C-42	22,700
C – Furnace cooled to 1080° F. and quenched in oil	B-94	11,000
D – Cooled from 1550° F. by blasting with carbo-nitriding atmosphere	B-98	12,600

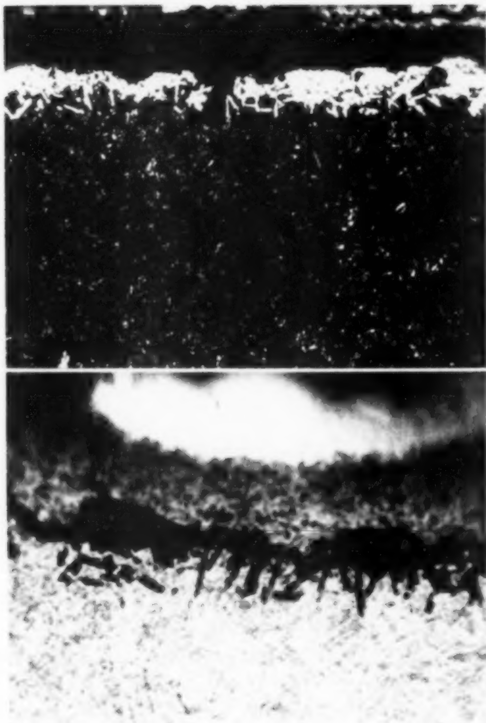
Effusion of nitrogen from the surface of a carbo-nitrided part apparently proceeds at a rapid rate. Figure 5 illustrates a denitrogenized layer which resulted from delay in getting the part into the quenching oil. Note the cementite layer at about 0.002 in. below the surface and the presence of inordinate amounts of dark phase between the cementite layer and the surface of the unetched sample shown at top right (opposite page).

Obviously, this dark phase may act as a stress-raiser, thereby decreasing the endurance of a part. Micrographs published by other investigators show the presence of this constituent but no mention has been made of it in accompanying text.

The coexistence of a cementite layer at the surface and a martensite layer slightly below the surface may cause undesirable tensile stresses, due to their different volume changes during cooling, and this may also be partially responsible for the lower endurance of carbo-nitrided test bars as compared to that of cyanided test bars.

The superficial hardness tests indicate that the surfaces of carbo-nitrided specimens were relatively soft. However, these same surfaces appeared hard to the saw or file. Microscopic examination of the microhardness test specimen clarified this apparent anomaly somewhat.

The low superficial hardness values obtained may be due to the effect of the dark discrete phase or void on the diamond penetrator. It may be noted in



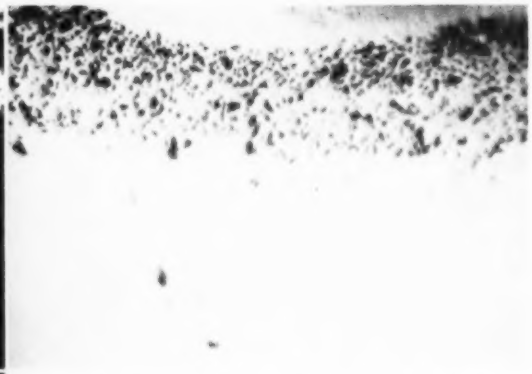


Fig. 5 – Denitrogenized Layer in Carbo-Nitrided S.A.E. 1024, Resulting From Delay in Getting the Part Into the Quenching Oil. Top left – 3% nital etch; 300 ×. Left – alkaline sodium picrate; 500 ×. Above – unetched, 500 ×

this connection that it is difficult to obtain accurate microhardness readings on cast iron containing graphite.

Results of bending tests (listed in Table II) indicate considerable difference in resistance to cracking under static loads. The only test bar which cracked without some degree of permanent deformation was 1024 steel carbo-nitrided and slowly cooled (Treatment A). This treatment was the only one that produced a cementite layer at the surface (Fig. 6), which would indicate that the cementite layer does not deform plastically prior to failure.

That some of the carbo-nitrided cases possess a slight degree of plasticity is indicated by those test bars which underwent permanent set prior to cracking of the case. Brittle failure, wherein the specimen broke through the case and the core, occurred when the core hardness was above Rockwell C-42. This probably was the result of undesirable surface stresses.

SUMMARY

The results of bending load tests, impact fatigue test, microhardness tests and microscopic examinations on test bars carbo-nitrided by four different practices indicated a considerable difference in fatigue strength between the test bars carbo-nitrided by the various treatments. Quenching in oil from 1550° F. is preferred for high fatigue strength.

It also appears that cyanide hardened test bars have greater resistance to fatigue failure than carbo-nitrided test bars, and also have a higher surface hardness.

Photomicrographs show the presence of a dark, irregular phase in the surface layer of all the carbo-nitrided test bars. It is thought that this may be graphite which precipitated from the austenite at the time that dissolved nitrogen was released during the cooling cycle.

Fig. 6 – Cementite Layer at the Surface of 1024 Steel Carbo-Nitrided and Slowly Cooled (Treatment A). 3% nital etch; 300 ×

By DURWARD ARMSTRONG, Chemical Engineer
Grumman Aircraft Engineering Corp.
Bethpage, L. I., N. Y.

Protective Finishing of Aluminum for Aircraft

CHEMICAL OXIDATION treatments for aluminum, or chemical films as they are referred to in Aeronautical Specification MIL-C-5541, are used extensively at Grumman Aircraft Engineering Corp., Bethpage, N. Y., where they have largely supplanted the slower and more expensive chromic acid anodizing process. In this treatment, marketed by American Chemical Paint Co., Ambler, Pa., under the proprietary name of "Alodine",* an acid solution is employed containing phosphates, chromates and fluorides† which produce an amorphous coating for paint bonding and protection against corrosion.

The basic requirements of specification MIL-C-5541, which are met by both spray and dip grades of Alodine, can be summarized as follows:

1. This specification covers one type of chemical film for aluminum and aluminum alloys.

2. Chemical films covered by this specification are intended for use as a paint base and as a corrosion preventive film for protecting aluminum and aluminum alloys.

3. Chemical films produced under this specification may be used instead of anodic films (Specification AN-QQ-A-696a) when specifically authorized by the procuring service.

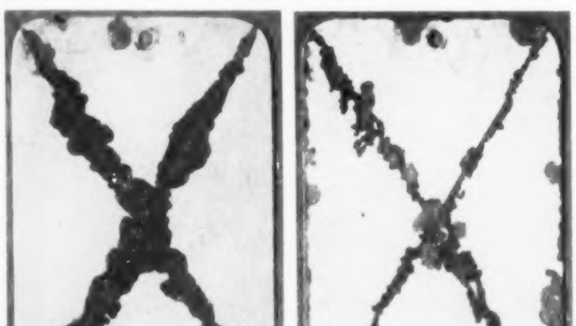
4. The chemical films covered by this specification shall be produced by suitable treatments controlled and operated to give a uniform product conforming to specified test requirements.

Unpainted aluminum not only corrodes when exposed in sea air or industrial fumes, but also sheds paint when such finish is applied directly to the metallic surfaces. Because of the protective nature of the naturally formed aluminum oxide, organic finishes on aluminum often give longer life in corrosive atmospheres than on steel or zinc. Nevertheless, great differences exist in the durability of the same paint finishes on aluminum panels which received different pretreatments. Some of these are shown in Fig. 2.

Simple treatments involving cleaning or etching or both do not change the chemical composition of the surface and have generally proved to be inadequate. Instead of retarding the corrosion of unpainted aluminum, these processes often have the opposite effect – they accelerate it. Another factor that influences degree of corrosion is the metallurgy of the aluminum itself. Commercial aluminum alloys, both wrought and cast, vary greatly in relative corrodibility.

Fig. 2 – Results of Exposure to Salt Spray of Aluminum Specimens Given Six Pretreatments Followed by Same Paint Finish. Time of exposure to salt spray shown in parentheses

Solvent Wiped (144 Hr.) *Alkali Cleaned (144 Hr.)*



*Trade mark Reg. U. S. Pat. Off.
†F. Spruance, U. S. Patent 2,438,877.

Fig. 1 – The F9F-6 Cougar Is the Latest Navy Fighter Produced by Grumman Aircraft Engineering Corp. This new jet aircraft utilizes Alodized aluminum for paint protection and metal preservation

The strong copper-bearing alloys are far more corrodible than the commercially pure metal.

Aircraft aluminum is usually "Alclad" which consists, for example, of a sheet of copper-bearing aluminum alloy sandwiched between two thin sheets of corrosion resistant aluminum alloy (Alclad 24S). Although the surface of the clad metal is highly resistant to corrosion under ordinary conditions, severe military service creates the need for a treatment which effectively seals the surface of the metal from oxygen and moisture. Sea air attacks untreated aluminum, and the formation of the natural white oxide ordinarily considered harmless can, even when it proceeds at a slow pace, ultimately undermine the strength of an assembly subjected to sudden and severe strains.

The United States Navy recognized these factors by specifying a protective treatment – chromic acid anodizing – for its aluminum flying boats shortly after the first World War. At that time, this was the only satisfactory treatment available.

Cleaning – Solvent cleaning removes oil without etching the metal, whereas phosphoric acid-solvent or chromic acid cleaners remove the oil and in addition etch the aluminum surface minutely. The value of an etched surface in improving paint adhesion seems to be negligible. Neither solvent nor acid cleaning improves the bond or the protective value of paint to any appreciable extent.

In general, where service includes exposure to corrosive conditions, paint-preservative coatings integral with the aluminum itself have proved to be far more effective than cleaning

Chemically Oxidized (800 Hr.) *Anodically Oxidized (1080 Hr.)* *Alodized (1280 Hr.)* *Acid Cleaned (144 Hr.)*

Chemical Films for Aluminum

and etching for bonding paint and enhancing its protection. These coatings fall into three classes depending on their composition: conventional crystalline phosphate coatings; oxide coatings; and the amorphous nonabsorptive coatings of the Alodine type used on Grumman naval aircraft.

While the conventional crystalline phosphate coatings will afford a good tooth and some increase in paint life, they provide less protection for the unpainted metal than is obtained with electrolytic oxidizing processes. However, these are expensive, laborious, or difficult in their operation. This is especially true of anodizing, which is generally accepted as the standard in aluminum protection. Grumman Aircraft Engineering Corp. obtains excellent protective coatings regularly and rapidly in a simple chemical process using Alodine. These coatings are equivalent in quality to those formed by the chromic acid anodizing process specified in AN-QQ-A-696a.

Grumman finishes its aluminum aircraft parts in four Alodine installations – the original dip pilot plant; two production-scale dip processes; and a spray process, which, incidentally, is the first spray treatment used on aluminum by the aircraft manufacturing industry.

Table I – Sequence of Operations in Dip Alodizing Line

Stage	Chemical	Concentration	Temperature
1	Ridoline, No. 3192	3 to 4 oz. per gal.	180° F.
2	Clean water	–	Room
3	Alodine No. 2	18 lb. per 100 gal.	110 to 120
	No. 100	10% by volume	
4	Clean water	–	Room
5	Deoxylyte No. 10	0.5% by volume pH 2 to 4.5	110 to 120

Sequence of operations is identical for each installation and consists of:

1. Cleaning the work with a buffered alkali.
2. Rinsing with clean water.
3. Coating the aluminum with Alodine.
4. Rinsing with clean water.
5. Rinsing the Alodized surfaces with "Deoxylyte"*-acidulated water.

*Trade mark Reg. U. S. Pat. Off.

Fig. 3 – View of Dip Alodizing Line. With the First Stage – Buffered Alkali Cleaning – in the Foreground. Parts are being removed from the rinse tank of Stage No. 2 prior to immersion in Alodine. Note the tumbling barrel attached to the right end of the overhead rack which also carries jet nozzles for spray rinsing

Fig. 4 – Three Panels Processed at Grumman's Bethpage Plant on Regular Production Line, and Then Exposed to Salt Spray for 250 Hr. (This is the minimum time required by Specification AN-QQ-A-696a, and is almost 100 hr. longer than the minimum time in salt spray required by MIL-C-5541.) Left, dip Alodized; center, spray Alodized; and right, chromic acid anodized, all unpainted

The final rinse is followed immediately by drying and then painting.

Dip Finishing – The first or pilot installation has five small tanks (stainless steel for the coating tank, carbon steel for the rest), each measuring 14½ in. long, 30 in. wide and 34 in. deep, and having a capacity of 60 gal. The first stage is heated to 165° F., and the third and fifth to 116° F. by means of strip heaters. Small parts that would be tedious or impossible to rack up in the conventional manner are processed either in a stainless steel tumbling barrel or small wire baskets. These are moved from stage to stage and up and down by means of a small overhead electric hoist.

Grumman's first production-scale dip Alodizing line, shown in the view opposite, utilized tanks which originally had served in a chromic acid anodizing process. The L-shaped tanks are 3 ft. wide over an 18-ft. length and 6 ft. wide over the remaining 6 ft. of length. Capacity of each is 3700 gal. Other data concerning this installation are given in Table I on the opposite page.

For processing, parts are placed in a stainless steel wire basket which is transported by a traveling overhead hoist. A tumbling barrel holding small items is usually attached to one end of the overhead rack and is transferred to successive stages simultaneously with the larger parts nested in the wire basket. The tumbling barrel is about 3½ ft. in diameter and is operated manually by means of a crank-and-gear arrangement. The barrel can be submerged almost two-thirds below solution level of the tanks during each operation.

Another feature is the provision for augmented rinsing. Three ¾-in. pipes equipped with full-jet and spray-jet nozzles run parallel with the longitudinal axis of the overhead rack. After the work has been lifted from the alkali bath and while it is draining over the rinse tank, the pipes are connected by a length of rubber hose to a convenient tap, and fresh water sprays over the work rapidly, thoroughly removing all alkali residues.

A second production line for dip Alodizing has been placed in operation in another building. This is similar in operational procedure and tank structure to the installation just described, except that it handles large aircraft assemblies.

Table II – Process Data for Spray Line

Stage	Chemical	Concentration	Capacity	Temperature	Nozzle Pressure
1	Ridoline No. 46 Ridosol No. 551	1¾ oz. per gal.	2800 gal.	140° F.	17 psi.
2	Clean water	—	785	Room (52° F.)	22
3	Alodine No. 100	10% (liquid)*	1500	110	18
4	Clean water	—	785	52	22
5	Deoxylyte No. 10	0.3%	785	110	22

*3 oz. per gal. (powder).

Chemical Protection for Aluminum

Spray Finishing – The spray Alodizing line is the only installation of its kind in the aircraft industry. Designed and built by Grumman, it was put in operation in September 1951. Parts that are to be assembled in the same building in which the line is located are hung on a mechanized conveyer passing through the washer tunnel and are sprayed by the chemical baths and rinses in the same sequence used for the dip method. Process data for the spray line are given in Table II. Following the final Deoxylyte-acidulated rinse, the work is air-blown to remove any excess liquid and the parts are then dried by hot air in an oven. The line speed is 17 ft. per min. minimum and 24 ft. per min. maximum.

Advantages – Preparation of the chemical bath consists merely of adding concentrated Alodine to the tank of the coating stage and then diluting with water to the required strength. Break-in time for the bath is short and, once used, it does not require further aging. Replenishment with the required chemicals keeps it in perfect operating condition.

To sum up, the advantages of Alodine which recommended the process to Grumman are: speed and capacity of the process; flexibility of the bath which allows immersion of aluminum parts for as much as 8 to 10 min. without adversely affecting the coating; uniform excellence of the coating; over-all economy. It has proved to be highly satisfactory in the reprocessing of defective or damaged parts if they are not too heavily covered with zinc chromate primer; the primed parts can be re-Alodized without harm to the organic finish.

Organic Finishes for Aluminum and Magnesium Aircraft Alloys

Among the subjects discussed at the Lacquer Panel featured at the 63rd Annual Convention of the National Paint, Varnish and Lacquer Association were requirements for organic finishes used on aircraft. Alfred E. Mallory, Bureau of Aeronautics, Department of the Navy, pointed out that coatings which have been satisfactory in the past lack certain properties necessary to provide optimum performance on high-speed aircraft. Some structural materials present serious adhesion problems. The leading edges of aircraft require a coating that will be resistant to corrosion and erosion from rain and snow at speeds in excess of 400 miles per hr.

Scuff resistance is required to withstand inevitable mishandling, foot traffic on the paint, and rough usage by maintenance personnel, particularly under combat conditions. Outstanding adhesion is needed to resist the excessive vibration, which may result in removal of the coating. Other desired properties are: *(a)* resistance to nonflammable hydraulic fluid for 1 week; *(b)* softening temperature above 250° F. before any indication of softening; and *(c)* low-temperature flexibility (–55° F.) as indicated by ability to withstand a 180° bend test around a ½-in. mandrel. One promising finish consists of a wash primer, plus a vinyl anticorrosive primer, followed by a vinyl-alkyd top coat.

Certain tests are useful in determining the suitability of finishes for aircraft requirements. The tape adhesion test and examination for absence of blistering are conducted on panels which had been in a humidity cabinet at 120° F. and 95 to 100% relative humidity for 30 days. After wiping off surface moisture, a piece of Federal Specification UU-T-106 masking tape is applied and then pulled off with one abrupt motion. The paint is examined for signs of failure. This examination should be supplemented by a microscopic study (using a binocular microscope at 30×) of a dry panel for physical characteristics. Properties such as tensile strength and elongation at rupture are best conducted on free films of the finish material prepared on amalgamated tin panels or by using other appropriate methods.

Finishes for aircraft hull bottoms should withstand soaking in water for several months without any impairment of adhesion or film properties. The incorporation of antifoulants to resist marine growth and attachment of barnacles is a very important additional requirement. Allen G. Gray

Fig. 1 – The 50-Kw. Induction Heater for Hardening Gears at Greenlee Bros. & Co., Rockford, Ill.

By L. G. MILLER, Chief Metallurgist
Greenlee Bros. & Co., Rockford, Illinois

Induction Heating Helps Produce Better Gears

INDUCTION HEATERS of the spark-gap, motor-generator or vacuum-tube type have proved their value and versatility in many applications. However, while their use is the answer to many production items, there are cases in which savings in cost, labor or time cannot be realized. Proposed applications of induction heating should, therefore, be carefully compared with other methods for these economies.

Here at Greenlee Bros. & Co. we are successfully employing induction heat in the treatment of gears. As a result, we are producing a smoother operating and quieter running gear because of the uniformity in finished size.

We use an Allis-Chalmers Model EI-50A vacuum-tube type induction heater (Fig. 1) having a rated output of 50 kw. and delivering about 2840 B.t.u. per min. Wired for 440-volt, 60-cycle, 3-phase operation, the rated input runs at 90 kw. The unit is basically a generator for converting commercial line frequency to radio frequency at about 400,000 kc., this frequency being usually referred to as "high frequency". Alternating current power enters through a 3-pole contactor into a 3-phase power transformer which steps up the line voltage which is then fed through a bank of six hot-cathode mercury rectifier tubes (type 869-B) whose function is to rectify the 60-cycle power and convert it to direct current at approximately 14,000 volts. This power is delivered through a radio-frequency filter to the plate of an oscillator tube (type 5770) which drives a tuned oscillator circuit. The latter, consisting of an oil-filled, high-voltage capacitor and a tank coil, converts the direct current to high-frequency current. Surrounding the tank coil is a single turn of copper sheet which forms the secondary of the output transformer. Attached to this turn are two copper busbars which serve as terminals for any one of the series of different work coils.

The heater is well equipped with protective devices to insure the safety of the operator and maintenance man, including automatic door interlocks to shut off the power when a door is opened. Working in conjunction with the heater is a closed "water-to-water" heat exchanger. This unit provides for mineral-free water to be circulated through the heater for cooling of the tubes, capacitors, work coils and such. This function makes the exchanger invaluable to the heater in that it prevents the formation of harmful lime deposits which would block the plumbing within the heater and cause overheating of the anode of the oscillator tube. The control of water temperature prevents the formation of condensation

on the lines within the heater which would be likely to cause damaging short circuits and high-voltage arcing.

The designing and building of work coils is too broad a field to describe here. Special literature is available on this subject. It will suffice to say that all of our coils for the gears are of single-turn construction. A piece of ⅛-in. thick copper strip the width of the teeth is bent to conform to the outside diameter of the gear and surrounded by ⅜-in. o.d. copper tubing for cooling. This is silver-brazed to ¼x1-in. busbars for mounting on the heater. So much for the heater and accessories.

The fact that our manufacturing operations cover a complete line of special machinery in addition to a standard line of automatic screw machine and woodworking machines indicates that we use an unusually large variety of sizes and types of gears. The majority are of a through-hardening grade of chromium-molybdenum steel in the 50% carbon range. A few gears in which the prime requirement is wear resistance rather than strength are of a carburizing alloy steel. The gear types are spur, bevel and helical. The tooth pitch ranges from 8 to 10 for about 90% of the gears. The bores are either a straight hole with a keyway or a splined hole.

For work handling, a completely automatic work table is, of course, the ideal arrangement, but the variety of set-ups and the short runs make this impractical for us. Our gears are manually handled, the only automatic phase being the time cycle for heating.

The complete processing of a gear would be: Cut off stock, rough turn, heat treat blank to Rockwell C-26, finish turn, broach hole, hob teeth, shave teeth, induction harden teeth to C-48 to 50, rebroach hole and put into stock for assembly. This covers the full routing of the part. Now let us give a breakdown of some of the operations.

Upon the arrival of the gear at the heat treating department for induction heating, the operator selects the work coil of proper size and otherwise sets up the job. An adjustable work rest is used to center the gear in the heating coil. The cycle is set to form a heat pattern to a point about ¼ in. below the root of the tooth; this distance will vary slightly with the gear size. At the end of the heating cycle, the power automatically shuts off and the operator manually quenches the part. Upon cooling, the gear is vapor degreased and tempered to C-48 to 50 in an air circulating draw furnace and then sand-blasted.

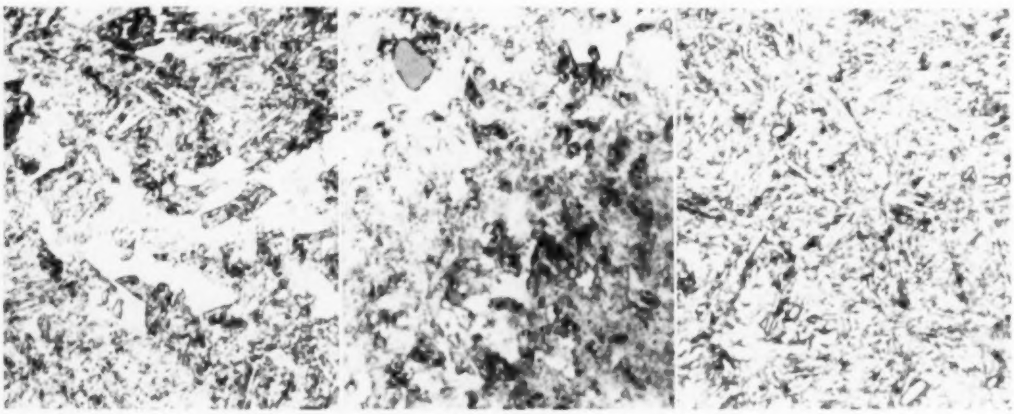


Fig. 2 — Microstructure of Induction Hardened Gears. Left — structure of unaffected metal. Center — transition zone. Right — tooth. 2% Nital, 1000×

The depth of heat penetration was determined through experiments on the strength of the tooth. Our gearing is subjected to a considerable amount of shock, yet must have some resistance to wear at the pitch line. Tests were made on a gear heat treated to Rockwell C-26 at the root and high hardness at the pitch line; this resulted in early failure of the tooth due to fatigue at the root. A penetration at the root to a hardness of C-48 to 50 gave the necessary strength at the stress point, which is at the root. The value of C-48 to 50 showed the necessary resistance to wear to warrant its adoption as the standard.

(Continued on p. 179)

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

Deoxidation Studies Show Advantages of Silicomanganese

Silicomanganese has proved to be highly efficient and economical as a furnace block and deoxidizer, as well as an alloy addition. Steel producers have found that it saves furnace time, produces cleaner steel, and increases the yield of rolled products.

Excellent Blocking Addition

When used as a blocking addition, silicomanganese stops the carbon-oxygen reaction in the open-hearth furnace and permits close control of analysis. The alloy has a ratio of approximately 3.5 manganese to 1 silicon. This proportion will produce a high degree of deoxidation in the furnace.

Why Silicomanganese Is Effective

The carbon boil is arrested more positively by this combination alloy, containing both silicon and manganese, than it is by larger amounts of silicon alone. As a result, close control of the carbon level can be maintained. Also, because of the low carbon content of silicomanganese, the heat may be blocked at a comparatively high carbon level. This saves furnace time, which is critical in reducing costs. Since silicomanganese gets more oxygen out of the bath than silicon alone, the steel is cleaner and has improved surface quality.

Metallurgical Studies Made

Work done by Herty and his associates (1) showed that manganese tends to flux silica inclusions resulting from deoxidation, and permits them to grow in size so that they float out of the bath more rapidly.

More recently, it was found by Hilty and Crafts (2) that manganese and silicon in combination lower the oxygen content much more than silicon alone (see Fig. 1). They also determined that, although manganese by itself is not a strong deoxidizer, it substantially intensifies the deoxidizing power of silicon.

It was shown that in steels with lower silicon contents (below 0.05 per cent), manganese in the amounts usually present as a residual has a strong influence. However, in the silicon range normally used for deoxidation (0.05 to 0.25 per cent), more manganese is required to obtain the full benefit of the combined deoxidizers. For example, at 1600 deg. C. iron with 0.10 per cent silicon and 0.10 per cent or less manganese contains about 0.017 per cent oxygen. With 0.50 per cent manganese, it contains only 0.009 per cent oxygen (see Fig. 1).

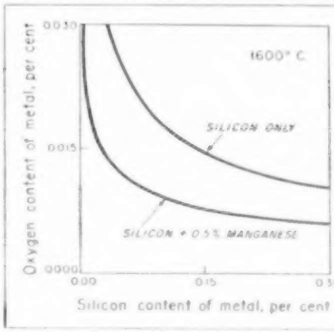


Fig. 1. Limit of solubility of oxygen in iron-silicon alloys, plain and with 0.50 per cent manganese at 1600 deg. Centigrade.

These data thus confirm an observation made by Tenenbaum and Brown (3) that steel as tapped from the furnace is materially lower in oxygen after blocking with silicomanganese.

In another study, made by Silliman and Forsyth (4) it was demonstrated that heavier than usual additions of silicomanganese result in a marked improvement in surface quality. About twice the usual addition of silicomanganese gives a substantial increase in the yield of finished product.

Silicomanganese Produces Cleaner Steel

Initial deoxidation in the furnace with silicomanganese produces very clean steel, particularly in grades below 0.25 per cent carbon. Several factors contribute to the cleansing action of silicomanganese. The amount of dirt in steel seems to be proportional to the maximum oxygen content prior to final deoxidation. Heats that are oxidized to a low carbon and recarburized, as were early rail and forging steels, are dirtier than those in which the carbon is "caught on the way down."

It is also well recognized that medium-manganese and low-carbon steels that are blocked at higher carbon (lower oxygen) contents, with low-carbon ferro-alloys, are cleaner than those taken to a lower carbon level and recarburized with high-carbon ferro-alloys. Silicomanganese is low enough in carbon to block at higher carbon levels. As pointed out by Tenenbaum (5), there is also a decided economic advantage in not driving to such low carbon contents before blocking.

Suitable For Ladle Additions

In addition to its use as a bath deoxidizer, silicomanganese has proved particularly effective as a ladle addition for the deoxidation of semi-killed steels. The alloy is also used to provide the complete ladle addition of manganese in the manufacture of medium-manganese, acid-steel castings.

Metallurgical Service Available

Our metallurgists will be glad to help you with the use of ELECTROMET silicomanganese. This alloy contains 65 to 68 per cent manganese, and is produced in maximum 1.50, 2.00, and 3.00 per cent carbon grades. All grades are furnished in a lump size of 75 lb. x 2 in. and in a crushed size of 2 in. x down. If you wish further information, please write, wire, or phone the nearest ELECTROMET office: in Birmingham, Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, Pittsburgh, or San Francisco. In Canada: Welland, Ontario.

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5. M. Tenenbaum, "The Economic Aspects of Deoxidation," Open-hearth Proceedings, 28, 1945, pp. 349-352.

Correspondence

Meaning Changed

London, England

You were kind enough to publish my letter "Hardness Measurements of Cemented Carbides", in the January 1953 issue, p. 142. However, the last two sentences in the published version have altered the original meaning of my text, which was: "With this indenter, we are able to produce suitable indentations in both soft, as well as hard materials, such as sintered carbides, silicon carbide, boron carbide, corundum, etc., with the exception of diamond where we hitherto only observed an elastic deformation which recovered after removal of the load."

The published text was: "With this indenter, we are able to produce suitable indentations in soft as well as hard materials, such as sintered carbides, silicon carbide, boron carbide and corundum. Hitherto we only observed in these hard substances an elastic deformation which recovered after removal of the load."

You will see that in your text the word "diamond" was replaced by "hard substances". Now, if it is stated in the first sentence that the double-cone indenter produces suitable indentations in hard materials, which means, causes a plastic deformation of these materials; this statement is contradicted in the second sentence that in these hard substances only an elastic deformation which recovered after removal of the load has been observed.

When looking at my original sentence, it was stated that only with diamond an elastic deformation which recovered after removal of the load was observed.

P. Grodzinski
Diamond Research Dept.
Industrial Distributors (Sales) Ltd.

Names of Phases in Alloy Systems

Urbana, Ill.

Physical metallurgists have often wondered about the unsystematic nomenclature attached to phase diagrams. Greek letters are sometimes used, like alpha iron, beta brass; latin capital letters in some ternary diagrams, like S and Z in the Al-Cu-Mg system; sometimes by chemical formulas, like $CuZn_2$, Mg_2Sn. At times usage may even overlap, so that a phase referred to by some authors as Cu_5Zn_8 may be designated also as gamma brass.

Furthermore, the assignment of Greek letters to various phases has been arbitrary. For instance, the sigma phase in the Fe-Cr system and the gamma phase in the Co-Cr system are isomorphous. In other situations the two ends of a continuous solid solution field bear different names. More such contradictions will appear as new phases are found in incompletely studied systems, or the nature of the older phases is more definitely known.

In an effort to do something about this, other than deplore the situation, Subcommittee 3 of Committee E-4 of the American Society for Testing Materials (of which the undersigned is chairman) has been engaged in studying an improved nomenclature for metallic phases, and has arrived at what appears to be a systematic scheme. It is outlined in the text starting on p. 136 of this issue. It is the Committee's hope that metallographers and physical metallurgists engaged in the study of phase systems will examine this proposal and send their comments to the undersigned.

Paul A. Beck
205 Transportation Bldg.
University of Illinois

Trees and Shrubs in This Landscape Are Corrosion Spots on Wire at 100 ×. From General Electric Co.'s Locomotive and Car Equipment Dept., Erie, Pa.

Personal Mention

James A. Parsons, Jr.

JAMES A. PARSONS, JR., ⊕ has resigned his position as manager of the laboratory at Duriron, Inc., Dayton, Ohio, in favor of a professorship in metallurgy at the Tennessee Agricultural and Industrial State University at Nashville. An additional duty will be coordinator of chemical, metallurgical and foundry engineering. A native Daytonian and a graduate in electrical engineering from Rensselaer Polytechnic Institute in 1922, Mr. Parsons worked at Duriron during two summer vacations while in college and was eventually lured to a permanent position – permanent until his present decision to enter the teaching profession. He was Duriron metallurgist from 1928 to 1945, when after the war he left the shop to develop the laboratory. Some nine patents, mostly in the field of heat treatment of metals, attest to his ability in both theoretical and practical metallurgy. His patents include an iron alloy, a method of making silicon compounds, a process for treating silicon iron castings, corrosion-resisting ferrous alloys, a cementation process in treating metal and an alloy vital to the making of stainless steel. The latter won wide acclaim at the time when Duriron leased the rolling rights to Carpenter Steel Co. Many honors have come to him as a result of his metallurgical discoveries, among them the Harman Award – $500 and a gold medal – received in 1927 for his work in science, and presented to him by the late Orville Wright, and an honorary doctor of science degree from Wilberforce University.

William O. Harms ⊕, formerly from the University of Minnesota, has recently been appointed to the staff of the Oak Ridge National Laboratory, an atomic energy installation operated by Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp.

Bernard P. Planner ⊕, metallurgical engineer and staff consultant for the James H. Knapp Co., Inc., Los Angeles, industrial furnace engineers, is engaged in compiling the results of a survey he just made for the company in Western Germany where he studied the postwar achievements and trends in the German metallurgical industry. Before coming to James H. Knapp Co., Dr. Planner had served as consultant to the U. S. Army Services of Supply and Army Intelligence, the Objectives Division of the Board of Economic Warfare, and several American industrial concerns.

Walter R. Buerckel ⊕, formerly on the sales administration staff of Nicholson File Co.'s Providence, R. I., headquarters, is now field representative for the company in the San Francisco - Oakland Bay Area. With the company since 1940, he has been field representative in Ohio, Pennsylvania and other states. For over three years he has lectured before technical groups on the metallurgy, application and abuse of hand files.

R. Genders, ASMember in London, England, has been appointed metallurgical consultant to Vanadium Corp. of America. Dr. Genders is deputy director of metallurgical research at the Royal Ordnance Factory, Woolwich, which deals with metallurgical problems of Britain's Army, Navy and Air Force.

Francis B. Herlihy ⊕, formerly assistant chief metallurgist, has been appointed chief metallurgist of the American Brake Shoe Co.'s research laboratories in Mahwah, N. J. He joined the company in 1945 after graduation from Massachusetts Institute of Technology.

T. T. Oberg ⊕ has resigned as a materials engineer and a consultant on fatigue and vibration of aircraft material and structural components with Wright-Patterson Air Force Base, Dayton, Ohio. His resignation is coupled with retirement from service with the Government after over 32 years service. Mr. Oberg will devote the next two years to travel, including the United States and abroad, and then will probably spend part of his time in consulting work on fatigue and vibration on structural aircraft materials and part structures. Mr. Oberg writes, "During the past 25 years that I have been a member of this Society, I have gained an unlimited amount of information in regard to the physical and mechanical properties of aircraft materials, published by the Society."

Tom Stott ⊕ has been appointed vice-president of H. M. Harper Co., Morton Grove, Ill. He joined the company in 1942 and was appointed general sales manager in 1950. He will also continue to serve in his capacity of general sales manager.

Edward H. Berry, Jr., ⊕, foundry manager, and **Henry J. Kelly** ⊕, chief engineer, have been elected to the board of directors of Dodge Steel Co., Philadelphia.

Norman F. Tisdale ⊕, manager of sales for Molybdenum Corp. of America, has been honored by Queen's University in Kingston, Ont., Canada, with an honorary degree of Doctor of Laws. A graduate of Queen's University in 1919 with degrees in chemical and metallurgical engineering, Mr. Tisdale has become widely known as a metallurgical authority, particularly in the development and sales of alloying elements in the production of ferrous and nonferrous metals. He is prominent in the development of boron applications in steel and iron, holding several patents on boron uses.

Personals

Herman A. Polderman, after 16 years at Caterpillar Tractor Co. in the engineering, metallurgical and purchasing departments, has joined Toledo (Ohio) Stamping Co. as assistant to the president. He is past chairman of the Peoria Chapter.

Victor D. Smith has returned to Columbia-Geneva Steel Co., Pittsburg (Calif.) Works, as development metallurgist in the development and process control department. He was recently released from the Air Force after 17 months duty at Wright-Patterson Air Force Base.

Roger F. Waindle, vice-president of the Cannon-Muskegon Corp., was elected president of the American Society of Tool Engineers at its recent annual national meeting in Detroit. **Harry B. Osborn, Jr.**, technical director, Tocco Div., Ohio Crankshaft Co., Cleveland, was elected second vice-president; **Raymond C. W. Peterson**, owner of the Peterson Engineering Co., Toledo, Ohio, was elected secretary; **Willis G. Ehrhardt**, partner, Ehrhardt Tool & Machine Co., St. Louis, was elected to the board of directors.

Robert R. Adams is currently serving as assistant to the director at Battelle Memorial Institute, Columbus, Ohio, and is in charge of Battelle Institute's newly established laboratories at Frankfurt, Germany. For more than a year he has been working closely with German scientists in the organization of this research center. The Frankfurt laboratories will be the German counterpart of Battelle Memorial Institute in Ohio, and will be staffed largely by German scientists working on the sponsored research problems of German industry.

James N. Wognum has been named chief engineer of Acme Steel Co.'s newly created engineering research laboratory in Chicago. He joined Acme Steel in 1933, first serving in the Cold Mill Division and metallurgical laboratory before transferring to the engineering department of the Riverdale plant. He then moved to the development engineering department of the Archer Ave. plant and in 1948 was named chief engineer of that department.

Personals

Robert E. Michaelis is with the National Bureau of Standards, Washington, D. C., in the spectro-chemistry section where he is in charge of spectrographic standard samples. During the last five years he was employed as chief spectrographer with the Pittsburgh Research and Development Laboratory, U. S. Steel Corp.

Dusan Pavlovic, formerly research engineer with Gibson Electric Co., Pittsburgh, has joined the metallurgical development section of the Westinghouse Electric Corp., East Pittsburgh, as a metallurgical engineer.

Marshall L. Kahl, formerly with Blackhawk Foundry & Machine Co., Davenport, Iowa, as sales engineer and later as purchasing agent, is now associated with A. Y. McDonald Mfg. Co., Dubuque, Iowa, as purchasing agent. During World War II Mr. Kahl was with the cast armor group, engineering division, Office, Chief of Ordnance in Detroit, and also with the inspection division, Office, Chief of Transportation.

Robert D. Grafmiller, formerly plant metallurgist, Warner Gear Division, Borg-Warner Corp., Muncie, Ind., is now a metallurgical engineer at Commercial Steel Treating Corp., Detroit, specializing on gas atmosphere furnaces.

The Trinks Industrial Heating Award, the nation's top honor for the industrial heating and related fields, was presented last month to four engineers: **Harry H. Harris**, president, General Alloys Co., Boston, Mass.; **Carl I. Hayes**, president, C. I. Hayes, Inc., Providence, R. I.; Carl F. Mayer, president, The Carl Mayer Corp., Cleveland, Ohio; and J. Spotts McDowell, technical assistant to the president, Harbison-Walker Refractories Co., Pittsburgh. The award is bestowed annually by a judges' panel to candidates nominated by the industry for the most notable contributions to economic or scientific progress in industrial heating. It was established in honor of **Dr. Willibald Trinks**, professor emeritus of Carnegie Institute of Technology and world authority on industrial heating problems. Mr. Harris was honored for his pioneering in heat resisting alloys and alloy casting designs for continuous furnaces. A noted inventor, Mr. Harris is believed to hold more patents on high-temperature tooling and furnace mechanisms than any other engineer. Mr. Hayes was recognized for his developments in electric furnaces and protective atmospheres. Notable among these was the Hayes "Certain Curtain" method of furnace atmosphere control which contributed to the heat treatment of metals without oxidation.

C. Robert Lillie, former project engineer for Standard Oil of Indiana, has been appointed research metallurgist in the metals research department at Armour Research Foundation of Illinois Institute of Technology. In addition to Standard Oil, he has been associated with the National Research Council, Washington, D. C., and Carnegie-Illinois Steel Corp. plants in Pittsburgh, Pa., and Gary, Ind. He expects to receive a D.Sc. degree in physical metallurgy from Carnegie Institute of Technology this month.

J. Myron Haniak was recently appointed understudy to the plant lubricant engineer for the metals research division, Olin Industries, Inc., East Alton, Ill. He was formerly employed by the Pittsburgh Area Smoke Control Bureau, and U. S. Steel Co., Homestead, Pa.

Personals

Rodolfo Sanchez C., who completed studies as a special student in metallurgical engineering at the University of Michigan this year, is employed as a metallurgist with Hojalata Y Lamina, S.A., Monterrey, Mexico.

Stuart T. Ross has resigned as assistant chief chemist and metallurgist at Harrison Radiator Division, General Motors Corp., to accept a position as project engineer, metallurgical research, central engineering, Chrysler Corp., Detroit.

Dilip K. Das, formerly a teaching fellow and research assistant at the University of Notre Dame, is now employed by the U. S. Naval Research Laboratory, Washington, D. C., as a physical metallurgist.

Peter E. White has resumed an appointment as assistant chief metallurgist with Messrs. J. B. S. Lees Ltd., West Bromwich, England, after completing a year's travel through Scandinavia, Western Europe, the United States and Canada, under a Mond Nickel Fellowship Award, surveying the production of high quality strip steels.

Herbert H. Uhlig has been promoted to the rank of full professor in the department of metallurgy at Massachusetts Institute of Technology. **Benjamin L. Averbach** has been promoted to associate professor in the same department.

Edward H. "Bob" Farmer, former Lockheed Aircraft Corp.'s works manager, has been elected vice-president – manufacturing at the Pacific Airmotive Corp., Burbank, Calif. Posts held by him at Lockheed included fabrication division superintendent, assistant chief tool engineer, plant engineer, and manufacturing control division manager.

Rollo W. Boring has been appointed sales manager of Rolled Alloys, Inc., Detroit. His previous work included metallurgical and sales work in heat and corrosion resistant alloys, industrial furnaces, and production heat treating.

James V. Burrell has been appointed sales representative of their Michigan District by Electric Furnace Co. of Salem, Ohio. He has been connected with the company for over 15 years in various departments including manufacturing, erection, service and sales. His new headquarters will be in Detroit.

Robert E. Parkinson has been appointed supervisor of materials research for Kawneer Co., Niles, Mich. He was formerly project engineer for the Continental Can Co., Chicago.

Four ASMembers were among the 31 "famous sons" honored at Case Institute of Technology's diamond jubilee recently. The awards were made to graduates of Case "who have distinguished themselves in their fields and in so doing have brought honor on their college". Recipients of the citations, their classes and the field in which they won the honor, were: **A. Allan Bates**, '25, vice-president of development and research, Portland Cement Assoc., Libertyville, Ill., research direction; **G. Brooks Earnest**, '27, president, Fenn College, Cleveland, technical education; **Fred L. Plummer**, '22, director of engineering, Hammond Iron Works, Warren, Pa., civil engineering; and **Kent Van Horn**, director of research, Aluminum Co. of America, New Kensington, Pa., metallurgical research.

Personals

Ray Bishop has been promoted from superintendent to manager of the Rock Island (Ill.) Works of J. I. Case Co., farm machinery manufacturers, Racine, Wis.

Walter R. Hibbard, Jr., has been appointed manager of the newly established alloy studies section in the General Electric Research Laboratory's metallurgical research department. The alloy studies section will carry on many of the activities formerly conducted by the materials and processes section. This latter section is now starting on a new program, under its manager, **James D. Nisbet**, which will be concerned with a broader effort in the application of research into materials and processes. Dr. Hibbard served in the Navy during World War II, attaining the rank of lieutenant commander, and after the war was assistant professor of metallurgy at Yale University. He joined G. E. Research Laboratory in 1951 as a research associate in metallurgy and in 1952 was made assistant manager of the materials and processes section.

Guy V. Bennett has become associated with T. C. Jarrett Co., Denver, and will devote his efforts to sales and engineering of the C. I. Hayes, Inc., line of heat treating furnaces and related equipment. His previous employment was with Douglas Aircraft Co., Tulsa, Okla., as materials and processes engineer.

Harley C. Lee has been elected a director of Basic Refractories Inc., Cleveland. He joined the company in 1926 and has been a vice-president since 1945. During World War II he was in charge of the technical department of Basic Magnesium Inc., a subsidiary of Basic Refractories at Henderson, Nev. For ten years prior to this position he was director of research for Basic Refractories.

William F. Ross has joined the staff of J. E. Von Mauer Co., Columbus, Ohio, sales representatives in Ohio, Eastern Indiana and Kentucky for Metalwash Machine Corp., Elizabeth, N. J. Mr. Ross was formerly sales engineer, designer and erection engineer with Electric Furnace Co.

Personals

John B. Fetherlin, process metallurgist at the Duquesne (Pa.) Works, U. S. Steel Corp., has been transferred to the U. S. Steel Research Laboratory, Kearny, N. J., for a year's training, at the end of which he will return to the metallurgical department at the Duquesne Works.

Louis P. Bokanyi, formerly with Wm. R. Thropp & Sons Corp., Trenton, N. J., is now sales manager for Falls Engineering and Machine Co., Cuyahoga Falls, Ohio.

John D. Altstetter, recently graduated from Ohio State University, is employed as a research metallurgical engineer at the manufacturing research department, Ford Motor Co., Dearborn, Mich.

Herbert W. Mishler has been discharged from active duty with the Ordnance Dept., U. S. Army, and has accepted employment at Battelle Memorial Institute, Columbus, Ohio, as a welding engineer.

H. C. Yaeger, who joined Jacobs Aircraft Engine Co., Pottstown, Pa., a subsidiary of Barium Steel Corp., in 1951 as chief metallurgist, has recently been appointed production manager. He brings to his new position wide experience gained during 15 years in the aviation industry.

Roger A. Long, formerly chief, metallurgical branch, fabrication division, Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics, Cleveland, is now associated with the aircraft components division of the Ferrotherm Co., Cleveland, as manager and chief engineer.

M. R. Bates has been appointed sales engineer at Alloy Precision Castings Co., Cleveland. Formerly with Reliance Steel Co. and Monarch Aluminum Co., for the past year he has been enrolled in Alloy Precision's company training program and has served in both the design and estimating divisions of the engineering department.

D. G. Taylor is now employed as a tool and production analyzer at International Business Machines Corp., Poughkeepsie, N. Y.

Personals

H. Neville Mason has retired from active service with Dominion Bridge Co., Ltd., Lachine, Quebec, Canada, after more than 40 years with the company. He joined Dominion Bridge in 1909 and during the next five years served in the head office in various capacities from draftsman to checker. In 1921 he was transferred to the Toronto office as contracting engineer in charge of design, estimating and sales. In 1937 he returned to the head office as warehouse manager, eastern division, a position he occupied (except for wartime duties) until his recent retirement. From 1941-42 Mr. Mason was warehouse steel controller at Ottawa and in 1944 was again released for service with the War Assets Corp. where he was responsible for the formation of a steel section. He is active in professional engineering societies and is secretary of the Montreal Chapter.

L. E. Grubb, former general superintendent of International Nickel Co.'s Bayonne, N. J., works, has been appointed general superintendent of the Huntington, W. Va., works. At the same time, **P. H. Flynn**, who had been assistant superintendent of the Bayonne works, was named general superintendent succeeding Mr. Grubb.

The following were elected officers of the Metal Powder Association at the Ninth Annual Meeting held in April in Cleveland: **Ernest H. Klein**, manager, metal division, New Jersey Zinc Sales Co., New York, elected chairman of the board; **Robert L. Ziegfeld**, re-elected acting secretary-treasurer; **George Roberts**, chief metallurgist, Vanadium-Alloys Steel Co., Latrobe, Pa., and Mr. Klein continue as directors.

John W. Putman was appointed chief metallurgist of the Engineered Precision Casting Co., Matawan, N. J.

Charles M. Ruprecht has been appointed vice-president of Electro-Alloys Division, American Brake Shoe Co., Elyria, Ohio.

R. W. Silverthorn was recently made supervisor of process engineering for AiResearch Mfg. Co. of Arizona.

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Personals

Evan J. Evans is now a metallurgical engineer with Amgears, Inc., a subsidiary of the Hupp Corp. in Chicago.

Ernst W. Farley, Jr., who has been vice-president and general manager of Richmond Engineering Co., Inc., Richmond, Va., for the past 15 years, has been elected to the presidency of the company.

Gerald V. Kingsley has been named research supervisor in the research division of Bohn Aluminum and Brass Corp., Detroit, and **Edward O. Falberg** has been selected as production metallurgy supervisor. Both will serve as assistants to **W. E. McCullough**, chief metallurgist. Dr. Kingsley has been associated with Bohn Aluminum for the past 12 years and Mr. Falberg has been connected with the firm for four years.

Dan D. Profant, formerly with Kencroft Malleable Co., Buffalo, N. Y., is now research engineer with the Carborundum Co. in Niagara Falls, N. Y.

Louis J. Privoznik has resigned as assistant research engineer with Standard Oil Co. of Indiana to accept a position as project welding engineer with A. O. Smith Corp., Milwaukee, Wis.

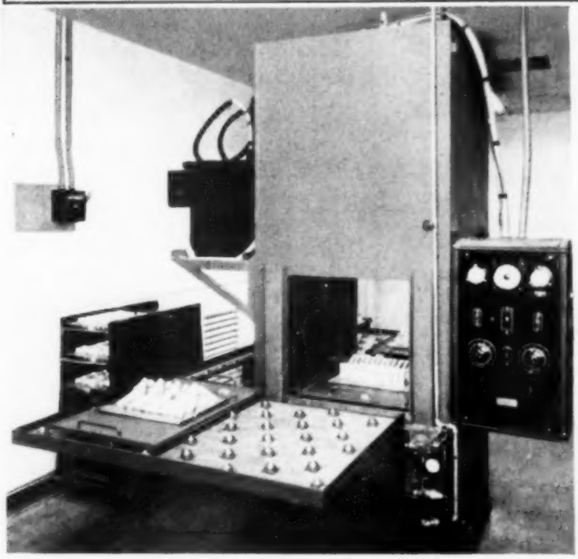
R. J. Prout has been transferred from the Geneva Works of Columbia-Geneva Steel Division, U. S. Steel Corp., to the Torrance, Calif., Works, as general supervisor of metallurgy at Torrance. He was chief inspector at Geneva.

Ralph V. Ross has resigned from the faculty of the State University of New York in Buffalo and is now president of Ross Motors, a Chrysler-Plymouth sales agency in Sodus, N. Y.

Edward P. Patterson is at present chief test engineer and chief metallurgist, Aircraft Division, White Motor Co., Cleveland, in charge of the aircraft laboratories.

Harold C. Templeton, formerly with Babcock & Wilcox Co., Barberton, Ohio, is at present assistant chief metallurgist with Lebanon Steel Foundry.

From aluminum castings...to battleship anchors...



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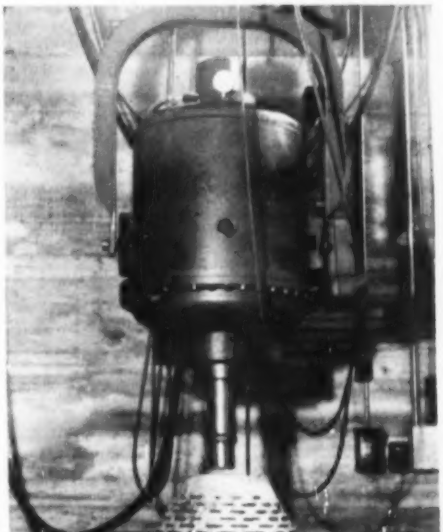

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Personals

James G. Hess has been released from active duty with the Air Force and has accepted a position as an engineer in the new process section of Titanium Metals Corp. of America, Henderson, Nev.

Birger L. Johnson, Jr., has left Mack Truck Co., Plainfield, N. J., where he was head of the metallurgy section, research division, for the past eight years, to accept a position placing him in charge of the metallurgical laboratory at Latrobe Steel Co., Latrobe, Pa.

Gerald D. Linke has assumed the position of vice-president and general manager of West Coast Loading Corp., Fontana, Calif. The firm is affiliated with Kwikset Locks, Inc., Anaheim, Calif.

John Alico has established a consulting engineering practice with offices in New York City, specializing in problems related to light metals fabrication as well as product and equipment design and other phases of the light metals industry.

Sigmund L. Fredericks has been transferred from the Cast Armor Division to the East St. Louis plant of American Steel Foundries. His position is that of chief chemist.

James S. Trees, after completing an extended student engineering training program with the company, has been assigned to the quality control department of Babcock & Wilcox Tubular Products Division, Beaver Falls, Pa.

Hugh B. Hix has resigned his position with E. I. du Pont de Nemours & Co. to accept a position with Ryan Aeronautical Co., San Diego, Calif., where he will work on titanium fabrication.

Oscar M. Wilt has been promoted from turn foreman to assistant superintendent, tin and terne coating department, Yorkville Works, Wheeling Steel Corp., Yorkville, Ohio.

John M. Parks, formerly of the Armour Research Foundation, Illinois Institute of Technology, is now associated with the Air Reduction Co., Inc., Research Laboratories, Murray Hill, N. J., as manager of the metallurgical division.

Rational Phase Nomenclature*

The present contradictions in phase nomenclature lie in the fact that at the time names were assigned to the phases occurring in binary systems, the corresponding ternary and more complex systems were not well known. Otherwise one could start, for instance, with a single n+1 dimensional phase diagram (n−1 composition variables, temperature and pressure) for the n elements to be considered. It would be easy to eliminate contradictions merely by assigning a name to each phase identified by a continuous field in the n+1 dimensional phase diagram, and which is separated from other phases by two-phase or multiple-phase fields. (Phase diagrams of lower complexity may be considered as sections through the n+1 dimensional phase diagram.)

Now if all sectional single-phase fields, derived from a certain n+1 dimensional phase field, would be given the same name when they occur in the separate sectional systems, obviously no contradictions could arise when the phase diagrams of lower complexity are combined into more complex diagrams. However, since actual knowledge progresses from simpler toward more complex systems, a systematic nomenclature could be practicable only if it were based on some other scheme assuring that each phase be assigned only one name.

It also appears that the most likely basis upon which a self-consistent and systematic nomenclature might be built is the crystal structure. It is known that phases with different crystal structure cannot be connected by a continuous solid solution. Although it is by no means certain that all phases with the same crystal structure which occur in sectional phase diagrams will combine into a single-phase field in the n+1 dimensional diagram mentioned above, self-consistency promises to be attainable by naming phases according to their crystal structures.

The basic requirements for a rational phase nomenclature may be summarized as follows:

(Continued on p. 138)

*By Subcommittee 3, A.S.T.M. Committee on Metallography. See letter on p. 112.

Phase Nomenclature

(Continued from p. 136)

1. A single system of nomenclature for all metallic phases.

2. Each phase should have only one name, uniquely identifying it.

3. The system should assure freedom from contradiction when phase diagrams of lower complexity are combined into more complex ones.

4. The symbols used for phase designation should be simple.

This last requirement prevents the use of phase designations for conveying additional information that is not necessary for its unique identification; otherwise, the designation would have to be undesirably elaborate.

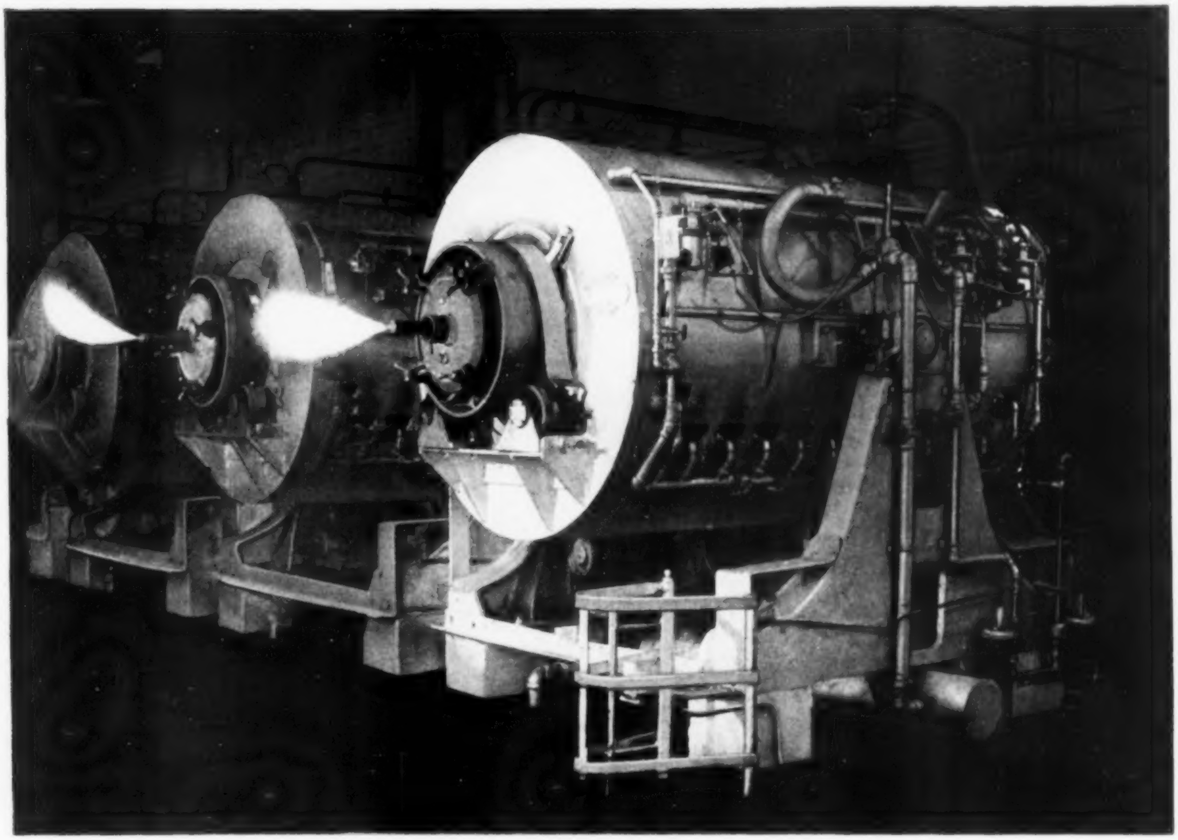
To meet these requirements the following tentative outline of a phase nomenclature for metallic systems is suggested:

The symbol for designating a phase should consist of two parts. The first part gives the chemical symbols of the elements occurring in the phase, listed in order of decreasing atomic percentage and placed in parentheses. The second part of the phase designation describes the crystal structure of the phase. An example would be (Cu, Zn) C2. Although this arrangement is generally applicable, it is particularly appropriate for typical metallic phases, such as electron compounds and phases with wide ranges of composition.

When it is desirable to emphasize that the phase consists of an uninterrupted series of solid solutions between the components, the chemical symbols of the elements may be separated by hyphens, for example: (Cu-Ni)C1.

When it is desired to suggest that the phase may be essentially ionic or covalent in nature, or that the use of a chemical formula is justified by the crystal structure, the mere listing of the components may be replaced in the parentheses by the suitable chemical formula, such as (Fe_3C) or (FeSi). However, in many instances where chemical formulas have been used in the part, the same phase was afterwards found to occur in analogous systems at varying atomic ratios – for example, the "sigma phase" at compositions approximately corresponding to $CrMn_3$, CrFe, and Cr_3Co_2. Other examples are pro-

(Continued on p. 140)



Phase Nomenclature

(Continued from p. 138)

vided by the electron compounds. In such cases, which probably include the majority of typically metallic phases, the chemical formula obviously cannot be justified on the basis of crystal structure or fundamental significance.

Whenever a phase designation is used in conjunction with a specific phase diagram on which the components are already indicated, the first part of the symbol may be omitted because here it would be not only unnecessary, but also too cumbersome and space consuming. For example, in referring to the face-centered cubic solid solution phase in the Cu-Zn system, it is sufficient to use the crystal structure symbol, since it completely specifies the phase referred to in the context. An exception should be made when a system has two separate phases of the same structure which can be distinguished by listing the components in the proper order; for example (Cu, Ag)C1 and (Ag,Cu)C1 designate the two face-centered cubic terminal solid solutions in the Cu-Ag system.

The second part of the symbol designating a phase should characterize the crystal structure with enough detail to distinguish between phases which are so different that they cannot form solid solutions with each other. Description of the crystal system alone would not be sufficient, since it would not differentiate between body-centered cubic and face-centered cubic phases, for example. On the other hand, it is undesirable to load down a designation with information on crystal structure of no importance as to its tendency to form solid solutions. Symbols for phase designations should obviously be as simple as possible. For this reason the use of the space group symbols adopted by crystallographers would be cumbersome and quite unnecessary.

It would certainly be preferable to use a recognized and existing system of symbols for crystal structure rather than invent a new one. However, no existing system, devised without regard to solubility relations as ours should be, possesses the required degree of discrimination. Furthermore, it is not even

(Continued on p. 142)

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Phase Nomenclature

(*Continued from p. 140*)

known as yet exactly how similar two structures have to be in order to be able to form solid solutions.

Other features desirable in a symbol are easy pronunciation, easy typing and printing, and adaptability to punched card techniques. These considerations favor the use of the Latin alphabet (either capital or lower case) and arabic numerals, without subscripts or superscripts.

We propose, therefore, that capital letters be used to designate the seven crystal systems, as follows: C for cubic, H for hexagonal, R for rhombohedral, T for tetragonal, O for orthorhombic, M for monoclinic and N for triclinic.

Within each crystal system, the metallurgically most important types of crystal structure are designated by numbers, following the capital letter corresponding to the crystal system. It might be well to start with the numeral 1 for the most closely packed structure in the particular crystal system, and to follow with successively higher numbers for less and less closely packed arrangements, as far as practicable. Thus, C1, C2 and H1 might designate face-centered cubic, body-centered cubic and close-packed hexagonal structures respectively.

It would also seem well to subdivide the structures in each system into not more than nine main groups. Further refinement to any degree could be carried out later except for affixing an additional number. For example, sub-groups C61, C62, C63 are all derived from C6, and differ from each other only in finer detail. Such a system would make it easy to recognize the main features of the crystal structure of a phase, while the existence of significant details would be clear, perhaps with the help of an explanatory table.

The letter S should be reserved for the designation of ordered structures. For example, if the body-centered cubic structure is designated as C2, the cesium chloride structure could be designated as C2S. Where different ordered structures are possible, these could be differentiated by numerals.

A problem to be considered is the designation of distinct phases in the

(*Continued on p. 144*)


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Phase Nomenclature

(*Continued from p. 142*)

same system which have the same crystal structure. For them, letters a, b, etc., could be affixed to the symbol. Thus, in the Al-Zn system the two face-centered cubic phases co-existing up to the critical point could be designated as C1a and C1b; above the critical point in the single phase field, the Al-Zn face-centered cubic phase could be designated simply as C1.

Sometimes it may be desirable, as a further differentiation, to change the sequence of the chemical symbols in the parentheses in the first part of the phase designation to correspond with the different predominance of the two elements. This device appears to be particularly useful when the two phases of the same crystal structure are terminal phases, so that their compositions are decisively different from each other.

Both kinds of differentiation might be used together. For example, in the Cu-Ag system the copper-rich solid solution might be designated as (Cu,Ag)C1a, and the silver-rich solid solution as (Ag,Cu)C1b. Again in ternary Cu-Ag-Au system, similar designations could be used in the composition range where two face-centered cubic phases co-exist; the simpler designation (Cu,Ag,Au)C1 would be sufficient when referring to solid solution alloys in the single-phase field.

If these designations are used in conjunction with a phase diagram, where the chemical symbols of the components are already shown, it would probably be unnecessary to use chemical symbols in the phase designations.

Finally, we propose that phases with unknown crystal structures should be designated by Greek letters. For example: (Mo,Ni)δ and (Mo,Ni,Fe)π. To each Greek letter would correspond a particular type of X-ray diffraction pattern, as yet unindexed, so that phases in different alloy systems having the same (unknown) crystal structure would be assigned the same Greek letter. When the structure is determined with certainty, the Greek letter in the phase designation would be replaced by the corresponding structure symbol. E. E. THUM

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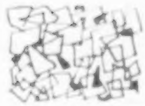

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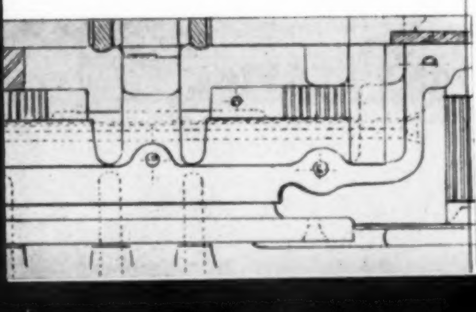

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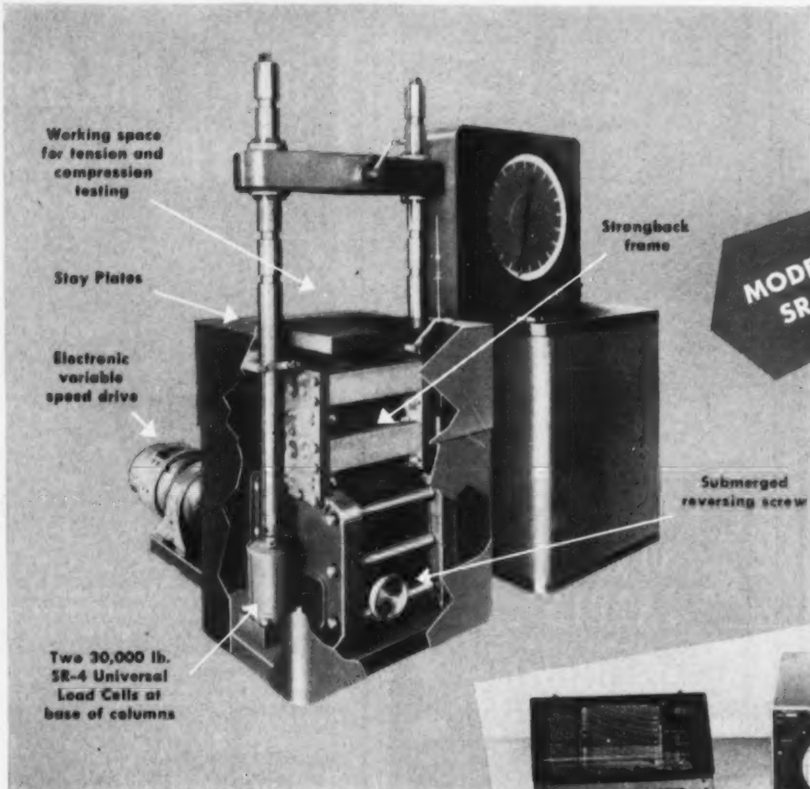

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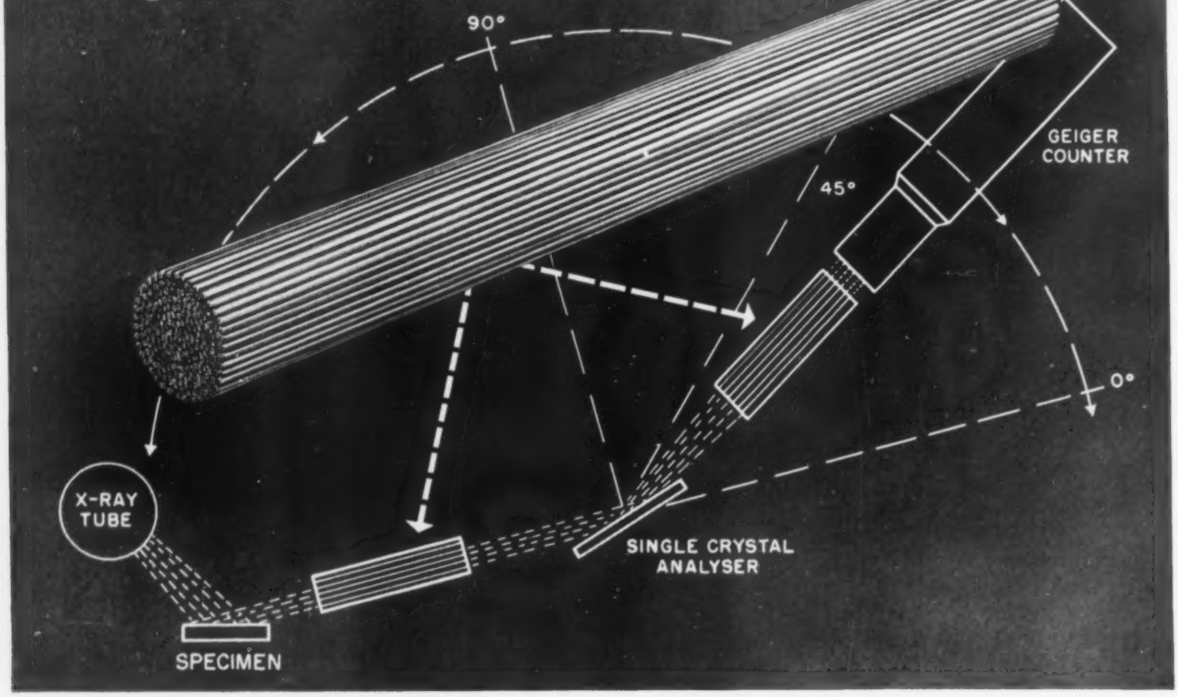

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By H. C. DILL, Chief Metallurgist, Hughes Gun Co.
and F. B. STERN, JR., Field Engineer, Magnaflux Corp., Houston, Tex.

Process Control in Gun Tube Manufacture

Cracked gun tubes reaching the finisher for final assembly mean not only loss of production and increased cost but also a loss of confidence in the quality of tubes being shipped – in this instance by the Hughes Gun Co., operators of Dickson Gun Plant, Houston, Tex. Rough turned, bored and heat treated gun tubes made by centrifugal casting must therefore be inspected for cracks, both on the outside and in the bore. Until the fall of 1951 white light was used for this inspection but cracks were difficult to locate because of heat treat scale, tool marks, and similar confusing evidences.

The Hughes Tool Co. (parent firm of the gun company) had for some time been using magnetic particle inspection to inspect oil well drill collars for discontinuities, and the possibility of applying this method to gun tubes was taken up with the local field engineer of the Magnaflux Corp.

Some three years previously, Magnaflux Corp. had developed a new nondestructive test using fluorescent magnetic materials for locating corrosion fatigue cracks on the inside of drill pipe. A special oil-tight boroscope and special small black-light bulbs of high intensity were developed for this work. It was found that these tools could also be used for Magnaglo inspection of gun tubes.

In principle, the tube is magnetized in such directions that cracks or discontinuities produce local magnetic leakage fields. When a suspension of ferromagnetic particles is applied to the magnetized part, the particles are attracted to the local leakage fields, thus outlining the cracks or discontinuities. In "Magnaglo" inspection, these particles are coated with a fluorescent material so that the outline of the crack or discontinuity glows when illuminated by black light.

This method was adopted for final inspection of gun tubes. In practice, the tube is placed on steady-rest rollers on a dolly, which is mounted on rails for moving into the light-tight inspection tunnel. A V-shaped tank at the bottom of the dolly contains the Magnaglo particles suspended in an oil distillate. A pump is used to agitate the bath as well as provide pressure for hosing the suspension onto the inner and outer surfaces of the tube.

A central conductor is inserted through the tube and electrical cables from the Magnaflux equipment (shown to the left of the operators in the photograph) are clamped to each end of the central conductor. The tube is then magnetized with half-wave rectified direct current at 1400 amp. The Magnaglo bath is flowed on the outside of the tube and over the breech and muzzle ends, and these areas are checked

Gun Tube on Dolly; Note Inspector at Rear With Boroscope. U-shaped coils magnetize tube longitudinally so external cracks can be observed under "black light". Inspection is done in a light-tight tunnel painted black

Inspection of Gun Tubes

for longitudinal or angular cracks, using black light. The tube is rotated half a turn on the rollers to complete longitudinal inspection of the outer surface.

The bore of the tube is then flooded with Magnaglo bath from the recirculating tank in the dolly. The tube is rotated during this operation to make sure that the inside surface is completely covered. The inspector at the rear center in the illustration is using the black-light boroscope to inspect for inside longitudinal cracks.

To locate transverse defects the tube is next magnetized longitudinally by passing it through an 8-turn spaced coil carrying half-wave direct current of 400 amp. The Magnaglo suspension is applied to the tube a short distance ahead of the coil so that inspection can be continuous, with two inspectors observing the top half-section of the tube between the spaced coils for circumferential cracks. The tube is rotated a half turn and pushed back through the coil to complete the inspection.

The inspected tubes are demagnetized by re-inserting the central conductor and switching the Magnaflux equipment onto alternating current, which is decreased to zero by an automatic 30-point tap switch.

During the year and a half that this method has been used by Hughes Gun Co., very few tubes have been rejected by the finishers because of cracks or discontinuities, and the method has been judged highly satisfactory.

OTHER USES FOR MAGNETIC PARTICLE INSPECTION

Magnaglo has also been used for process control. For example, by inspecting tubes before and after heat treatment it is possible to determine if cracks occur during this phase of manufacture. Likewise, a program is being initiated to spot-inspect rough-turned gun tubes while still in the lathe. Local areas where cracks might exist are magnetized with prods attached to light, portable Magnaflux equipment. Black Magnaflux paste shows up cracks by the so-called "residual" method.

Gages, tools, and many small parts are likewise inspected for cracks on receipt. The method is used in the reworking of tools and dies, and in the maintenance and rebuilding of highly stressed plant equipment.

Welding Malleable Iron*

Welding of malleable cast iron presents a special problem because of the inevitable hardening which occurs on heating and cooling. Malleable iron is produced by annealing low-silicon white cast iron. It is termed "whiteheart" or "blackheart" malleable, depending upon whether it has a coarse, steel-like fracture or a uniform, silky black fracture. The annealing procedure used determines which type results.

(Continued on p. 164)

*Digest of "Welding of Malleable Castings", by T. J. Palmer, *Foundry Trade Journal*, Vol. 93, Dec. 11, 1952, p. 667-672.

Welding Malleable Iron

(Continued from p. 162)

Because of the reactive packing medium used in annealing to produce whiteheart malleable, the thicker casting sections usually show considerable structural variation from exterior to interior, with an outer band of decarburized iron followed by a zone of ferrite and pearlite, merging into a core of coarse pearlite. Some temper carbon occurs in both of these zones. In thin sections almost complete decarburization takes place, resulting in an all-ferritic structure.

In the anneal which produces blackheart malleable an inactive packing medium is used, which encourages the development and growth of graphite nuclei. The extent to which this growth progresses is dependent upon time at temperature and speed of cooling. Since little or no decarburization occurs, a uniform structure of ferrite interspersed with islands of graphite will be produced. Such a uniform structure is obtained with whiteheart malleable only in very thin sections. Here the structure is practically all ferrite. Whiteheart malleable is somewhat tougher and stronger, although harder and less ductile, than blackheart.

In spite of these differences an important similarity exists from the welding viewpoint in that a certain amount of free carbon or graphite is present which causes microstructural instability above 1382° F. The only joining processes that can be used below this temperature are soft soldering and silver brazing.

The changes which occur upon heating to high temperatures apply to both types of malleable, but this study of weldability is largely confined to blackheart because it is the more uniform metallurgically of the two varieties. The reactions that occur in malleable iron at fusion welding heat are of a more stable nature than those that occur in the welding of steels, and the author states that the fusion welding of malleable cast iron is, in fact, quite impractical.

Examination of samples of blackheart malleable heated to various temperatures from 1430 to 2330° F. shows that a reversal of the original annealing cycle occurs in a fraction of the time it took to complete initially. The ferritic matrix changes to a carbide network surrounding islands of pearlite.

In fusion welding such materials, similar changes take place at these temperatures but the tendency would be for such changes in structure to be localized around the temper carbon islands in the original malleable structure. Since the time factor is of minor influence in this reversal, the various structures represented by temperature would be present panoramically and the heat affected zone would show progressive hardening right up to the bond between weld metal and base metal. The type of filler metal or fusion welding process used would not affect this progressive hardening.

Porosity will occur to some extent whenever malleable iron is heated close to its melting point. This porosity results from shrinkage brought about by structural adjustment; it occurs if the malleable is heated to 2100° F. or above. Hence, commercial fusion welds will exhibit some porosity near the bond.

PRACTICAL WELDING METHODS

Some repair welds of malleable iron made by electric arc process with nickel alloy electrodes have stood up quite well but others have failed because of poor ductility. The

(Continued on p. 166)

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Welding Malleable Iron

(Continued from p. 164)

dual effect of a lower operating temperature and the presence of nickel appears useful and, although such joints are not malleable, they seem "tolerably satisfactory" in practice.

The amount of massive carbides present in the heat affected zone is noticeably less than in full fusion welding, and porosity in the region adjacent to the bond is also reduced. Small electrodes and low welding currents are required.

Bronze welding is the recognized process for welding malleable iron castings since temperatures are never much in excess of 1700° F. The parts are prepared for welding ordinary cast iron. Bronze welding should be performed at minimum temperature with a torch tip slightly smaller than for regular welding and a slightly oxidizing flame. A small amount of filler metal first spreads out and "tins" the base iron; the process thereafter consists of building up with the tinning action always just ahead of metal deposition. Protracted cooling is not required, since the joint is heated only locally to a dull red before welding is started. The risk of cracking is almost nonexistent.

Malleable iron castings can be brazed satisfactorily by using a minimum heat input and a low-melting brazing metal. Good temperature control is necessary and the temperature should not exceed the melting point of the brazing alloy by more than 120° F.

The author concludes that preheating of malleable castings before welding is to be strongly discouraged. Once massive carbides have formed in the parent metal as a result of heating or welding, there is small hope of breaking them down and regaining ductility by normal post welding treatment; the effect is permanent for all practical purposes. With bronze welding, satisfactory joints are obtained with a minimum heat input and this process is recommended for repairing or assembling malleable castings.

[Abstracter's Comment – It is to be regretted that this excellent discussion did not touch upon the possibility of welding malleable iron with a filler rod of silicon cast iron followed by a malleableizing heat treatment. This procedure has been followed with some success in isolated cases.]

W. L. Warner

Forming of Aluminum*

Generally speaking, aluminum can be formed by such well-known methods as plain bending, drawing, stretching, roll forming, hammer forming, forging, coining, stamping. Occasionally there are new techniques being employed; however, most generally they are a variation or modification of an older one and are usually applicable to a specific product or problem.

The forming of any aluminum alloy can be accomplished to a greater degree and with greater ease if it is in the annealed condition.

(Continued on p. 168)

*Digest of paper by E. V. Sharpnack, Reynolds Metals Co., presented before Engineer Research and Development Laboratories, Fort Belvoir, Va., March 30, 1951.

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Forming of Aluminum

(Continued from p. 166)

Almost equal in formability are the heat treatable alloys in the as-quenched condition, providing the work is done soon after quenching. Refrigeration holds such quenched alloys in highly ductile condition for a long period of time.

The formability rating of strain-hardened alloys is determined by two things; first, the chemical composition of the alloy and, second, the degree of strain-hardening imposed. Commercially pure aluminum (2S) forms better in the strain-hardened condition than an aluminum alloy of the same gage and with the same degree of strain-hardening. Likewise, an aluminum alloy with only one major hardening constituent forms better than an alloy with two or more. For instance, alloy 3S (Al-Mn) and C50S (Al-Mg) forms better than 4S (Al-Mn-Mg). The same holds true for 52S (Al-Mg) which forms somewhat better than 4S even though its mechanical properties are considerably higher.

Among the heat treatable alloys, 63S (Al-Si-Mg) with its lesser quantities of hardening elements, forms better than its companion alloy 61S. Likewise, R301, with its greater quantities of hardening elements, does not form quite as readily in the fully heat treated condition as alloy 24S. Alloy 75S consists of several hardening agents and is particularly high in zinc and is the most difficult of all to form and fabricate successfully. However, recent developments indicate that this alloy (75S-T6) can be formed very nicely in the fully heat treated condition at temperatures of 275 to 300° F. without appreciable sacrifice in mechanical properties. In fact, any aluminum alloy can be formed more easily at an elevated temperature than at room temperature; however, excessive temperatures tend to encourage grain change and loss in strength and corrosion resistance.

It must be remembered that certain alloys, particularly those of the Al-Mg group, work-harden considerably faster than the others; such alloys should not be expected to draw as well as 2S or 3S which work-harden at a slower rate.

Reynolds Metals Co. manufactured several sizes of medical chests for the Armed Services during the last war. The chests were made to government specification using alloy 52S-O, with walls 0.091 in. thick and up to 12 in. deep. By calculating the necessary blank size and figuring the percentage reduction from blank size to shell size, we obtained a reduction figure of approximately 35%. This is not the maximum reduction often obtainable with 52S-O; a 41% or 42% reduction should be possible. However, in order to produce a shell to such a reduction in this type of draw, the metal must be produced with physical properties and hardness on the minus side of established typical values. In other words, the maximum degree of accomplishment obtainable in drawing or in any other forming operation is as much a metallurgical problem as it is a tooling problem. Closely controlled metal must be produced for the deeper shells or they will, of necessity, have to be made in two draws. If the alloy used were 2S-O,

(Continued on p. 170)

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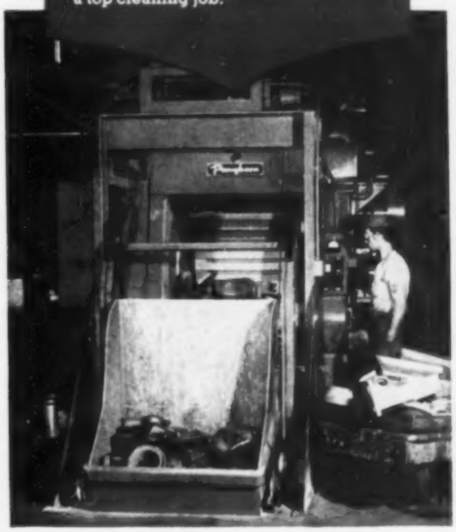

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USERS of the Pangborn Blastmaster ROTOBLAST® Barrel know that Blastmaster's exclusive features pay off in better, faster, cheaper cleaning! They praise features like the abrasive-tight door that prevents waste . . . the automatic throw-out torque arm that protects machine and operator . . . the work conveyor that will not clog or pinch . . . the easy-to-adjust conveyor take-up. And Blastmaster incorporates the famous Pangborn ROTOBLAST that does a *better* job and saves you money by saving you time, labor, space, power and tools!

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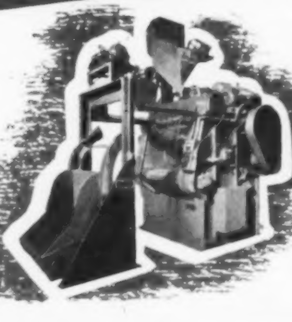

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BLAST CLEANS CHEAPER

with the right equipment for every job

Forming of Aluminum

(*Continued from p. 168*)

3S-O or C50S-O, it would probably be possible to draw the deeper shells in a single operation without the necessity of exercising such precise metal control or resorting to additional processing operations.

The limiting factors then, in deep drawing, are the physical properties of the metal as received from the mill. If they are above typical values, the accelerated degree of work hardening during the actual drawing of the shell will have a pronounced effect on the result.

Stretching is a forming operation that is being increasingly employed, particularly for parts of aluminum sheet and shapes. Its one big advantage is the elimination of excessive spring-back. In stretch-forming shapes it is ideal if every fiber in the part can be stressed in tension, thus avoiding any wrinkling; however, this is usually impossible so provision must be made in the forming block to support and confine the metal that is subjected to compressive stresses.

The usual procedure in stretch-forming is to apply an initial stress in the elastic range in the original shape, and follow this by a higher stress in the plastic range as the contour forming progresses. A uniform and steady forming stress gives the best results, but it is sometimes necessary to apply a final setting stress. Maximum stretcher stresses are always at the jaws; therefore, the actual forming is done at somewhat lower stresses. Since the stretch-forming is done in the plastic range, extreme care must be employed where this range is small. In most jobs a combination of bending and stretching is worked to a definite advantage. Stretch-forming causes an increase in the length of a part and consequently a decrease in cross-section. Stretch-forming semi-hollow or irregular shapes generally requires the use of flexible fillers to avoid excessive distortion of the part, particularly if close tolerances are necessary.

Tube forming is another type of forming that is in extensive use; but, unfortunately, there are very few dependable data published on minimum bend radii for the various available aluminum alloys. Trial and error methods still prevail. Generally speaking, alloys having the greater stretch properties, which also have the necessary requisite to absorb compressive stresses, will form on smaller radii; however, the thinner the wall thickness the more difficult the tubing is to form. Smaller radii and better forming can be accomplished on conventional power tube forming machines than by hand-forming methods.

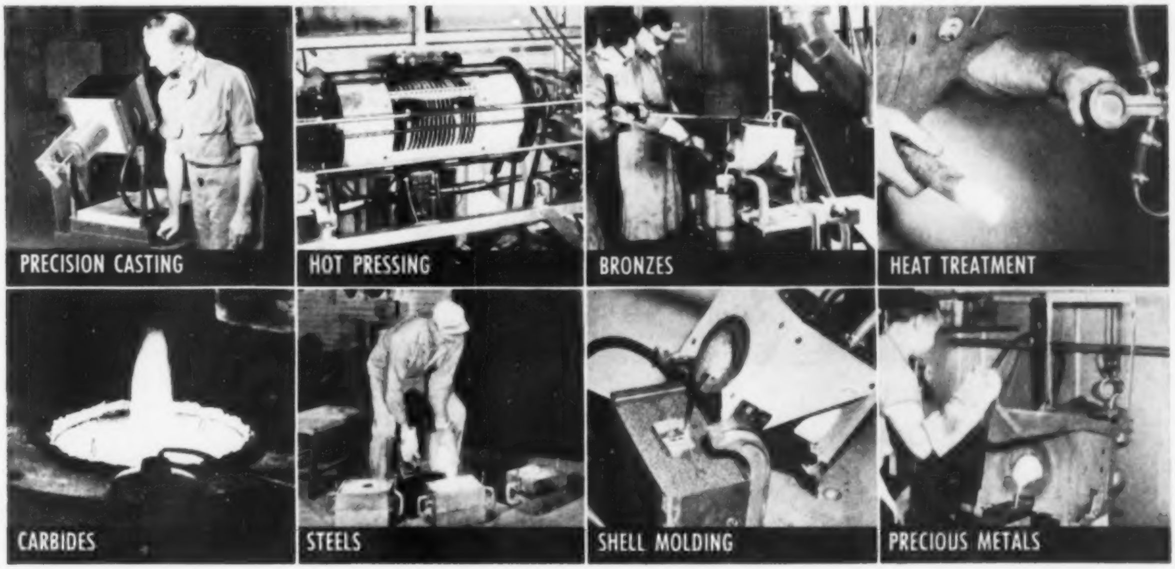
Chromium-Nickel Steels Alloyed With Nitrogen*

In view of its beneficial effect on the properties of a variety of alloy steels, the use of nitrogen as an alloying element is constantly increasing. The object of this research was to investigate the following factors: (*a*) The maximum amount of nitrogen that can be absorbed by the steel without impairing the quality of the ingot or casting, (*b*) the ratio of nitrogen in the charge to that retained in solid solution, and (*c*) the loss of nitrogen in the liquid steel as a function of the melting procedure.

A steel with about 17% Cr, 10% Ni, 0.1% C and low molybdenum was prepared in an induction fur-

(*Continued on p. 172*)

*Digest of "The Problem of Making Nitrogen-Alloyed Chromium-Nickel Austenitic Steels", by V. I. Prosvirin, N. S. Kreshtshanovskiy and R. P. Zaletayeva, *Liteynoe Proizvodstvo*, 1952, No. 9, p. 22 to 23.



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The 20 kw. converter will melt 17 pounds of steel in 40 minutes. Maximum capacity is 30 pounds of steel or 60 pounds of bronze. The larger 40 kw. unit melts faster, will handle up to 50 pounds of steel. The 6 kw. unit melts a pound of steel in 8 minutes. Controlled temperatures to 4500 deg. F and higher make these furnaces ideal for sintering and hot pressing carbides.

Ajax-Northrup converters are compact and self resonating. They require no special foundation or wiring—and they're certified to meet F. C. C. regulations.

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AJAX ENGINEERING CORPORATION

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Chromium-Nickel Steels Alloyed With Nitrogen

(Continued from p. 170)

nace from clean low-carbon scrap, ferrochrome of 0.04 to 0.12% C, electrolytic nickel, ferromolybdenum, and the usual additions. Nitrogen was introduced as nitrided ferrochrome (0.04% C, 65% Cr, and 2 to 3% N). This was added in small portions underneath the slag, shortly before teeming and with bath temperatures at 2770 to 2800° F. Higher temperatures should be avoided because the solubility of nitrogen in the chromium-rich bath increases rapidly with temperature. Since only a limited amount of nitrogen can be retained in solid solution, the excess is liberated as a gas during solidification, causing porosity. With high nitrogen in the bath, not only the top portion but virtually the whole ingot is full of pores and blowholes.

About 40 ingots were cast, and samples taken from the same position of each were analyzed. When the charge contains 0.5% N, a little more than half of it is retained in the solid steel in solution. This figure remains constant at about 0.3%, even if the nitrogen in the bath is increased to 1.5%. With higher nitrogen in the bath, the ingots were invariably porous. The optimum nitrogen content for steels with 15 to 17% Cr is 0.15 to 0.20%, or about 1% of the chromium content of the steel.

To assess the loss of nitrogen caused by temperature and time, a larger ingot with 0.28% N was cut into smaller specimens and these were remelted individually in the same induction furnace. Each of the sample melts was then brought to a different temperature between 2550 and 2820° F. and held for 5 to 30 min. before pouring. After 5 min. at 2550 and 2820° F., the nitrogen content fell from 0.28% to 0.26 and 0.23%, respectively. After 30 min. the figures were 0.23 and 0.21%. It can be thus concluded that reasonable differences in melting practice do not lead to a significant loss of nitrogen in the metal.

Apparently, the large proportion of chromium allows the bath to retain much more nitrogen in solution than could unalloyed iron.

N. H. POLAKOWSKI

Corrosion of Spot Welds in Low-Alloy Steel*

Structural spot welds, such as those used widely in fabricating railroad equipment, are subject to corrosion from service environments, requiring preventive measures to avoid premature failures. A basic knowledge of corrosion phenomena in spot welded joints of low-alloy high-tensile steel and an evaluation of the beneficial effects of protective weld sealers will help to prolong service life of such equipment.

Service failures of structural spot welds from atmospheric corrosion usually are represented by a plug-type failure, although occasionally they may fail by shearing at the faying (that is, mating) surfaces of the joint. The cause of this difficulty is inadequate joint preparation and improper maintenance.

Superior corrosion resistance of spot welded joints in low-alloy high-tensile steel can be demonstrated readily by comparative atmospheric corrosion tests of both spot welded and riveted joints in low-alloy steel, copper-bearing mild steel and plain mild steel. An advantage of this enhanced corrosion resistance is shown by the much better adherence and life of protective coatings.

Unprotected low-alloy steel joints, without any spot weld primer or sealer, may start to crack at the edge of the welds after one year of atmospheric corrosion, and fail completely after 3½ years of exposure. With a proprietary sealer in the joint, the start of corrosion cracking is retarded beyond 4½ years. The ultimate in protection is the use of both spot weld primer and sealer in each joint, plus a tempering treatment in the spot welding machine. Other approaches are to design the joints for automatic submerged-arc welding or mash-seam welding to eliminate lap joints. In some applications the use of more corrosion resistant materials may be the answer.

Mechanism of the corrosion process resulting in the failure of low-alloy steel spot welds encompasses many factors, among which is the effect of corrosive solutions which (*Continued on p. 176*)

*Digest of "Corrosion of Structural Spot Welds", by B. Karnisky, E. Kinelski and E. Gruca, *Welding Journal*, Vol. 31, October 1952, p. 903-916.

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N-A-X HIGH-TENSILE, having 50% greater strength than mild carbon steel, permits the use of thinner sections —resulting in lighter weight of products. It is a low-alloy steel—possessing much greater resistance to corrosion than mild carbon steel, with either painted or unpainted surfaces. Combined with this characteristic, it has high fatigue and toughness values at normal and sub-zero temperatures and the abrasion resistance of a medium high carbon steel—resulting in longer life of products.

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Your product can be made lighter in weight . . . to last longer . . . and in some cases be manufactured more economically, when made of N-A-X HIGH-TENSILE steel.

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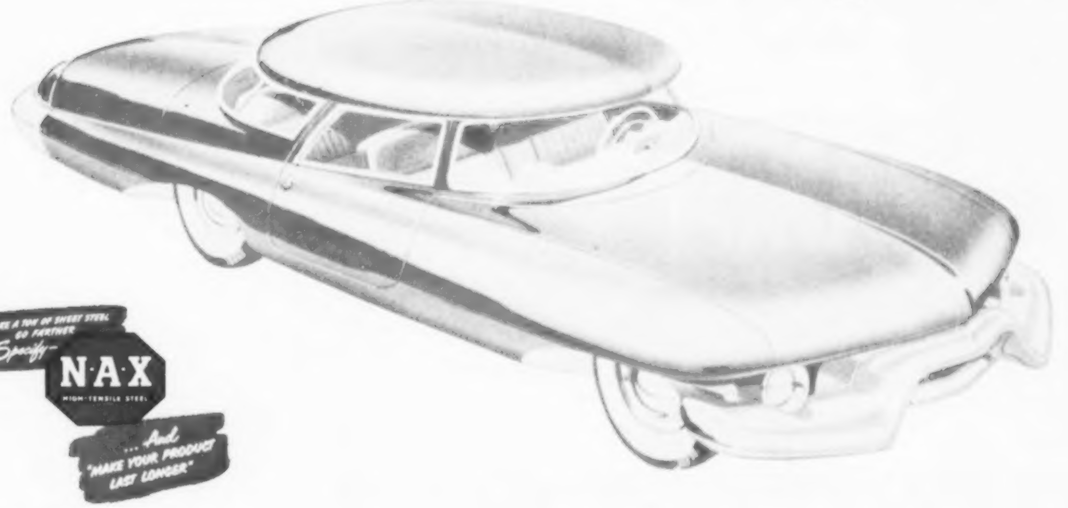

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KEEP YOUR SCRAP MOVING TO YOUR DEALER

Corrosion of Spot Welds in Low-Alloy Steel

(Continued from p. 174)

may drain and collect at spot welded joints. This involves not merely the dissolution of the metal at the joint by chemical attack, but even more seriously the destruction of certain protective paint and caulking compounds. It can be demonstrated that a dilute acid solution will not penetrate into a welded joint sufficiently to corrode the spot weld periphery without first weakening the parent metal to the point of failure. However, once the protective coating at the edge of the joint is destroyed, ordinary atmospheric exposure can produce sufficient corrosion in the joint to cause failure of the welds.

Once rusting has begun in the joint, moisture can be retained for long periods of time. The actual process of corrosion in the joint is most likely by an oxygen concentration cell action. The moisture in the rusting joint is saturated with oxygen at the outside, low in oxygen inside. The metal in contact with the solution at the low oxygen concentration point is anodic to the high oxygen concentration portion and therefore corrodes preferentially.

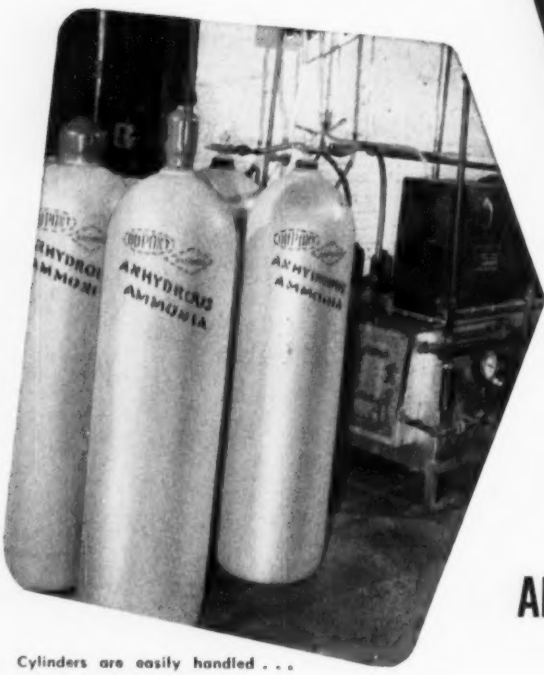
Wetting and drying accelerate spreading of the joint. The rust formed during wetting expands and hardens during drying, so that the joint is spread a slight amount. The next wetting penetrates further into the joint. Thus a thin, hard wedge of rust drives itself up to the spot weld. Low-alloy steels form a hard, tight rust which is a primary reason for their good resistance to corrosion. However, this property is harmful inside a joint because of the extra pressure developed.

A small zone of partial fusion, commonly called the corona fusion zone, exists around the spot weld periphery at the faying surfaces of the joint. Expansion of the joint resulting from the wedge of corrosion products readily cracks the corona fusion zone, the resulting sharp notch providing entrance into the weld nugget. Concentrated stresses at this location, combined with a corrosive medium, develop a stress-corrosion crack. If the stresses are developed only by the expansion of

(Continued at bottom of p. 179)

As an economical source of nitrogen and hydrogen for annealing non-ferrous wire . . .

Fine, non-ferrous wire being uncoiled and entering the annealing furnaces.



Cylinders are easily handled . . . take up minimum of working space.

The Nesor Alloy Products Company uses Du Pont "National"* ANHYDROUS AMMONIA IN CYLINDERS —99.99% PURE AMMONIA

For annealing fine non-ferrous wire, The Nesor Alloy Products Company uses Du Pont "National" Anhydrous Ammonia as a dependable source of hydrogen and nitrogen. Dissociation of one 150-pound cylinder yields 5100 cu. ft. of hydrogen, and 1700 cu. ft. of nitrogen. The controlled atmosphere produced with these gases is used effectively for a wide range of metals, including nickel, Monel, stainless steel, brass and bronze.

The high purity of Du Pont "National"—99.99% Ammonia—makes possible a more inert atmosphere. There are fewer shutdowns for removing oil deposits from catalysts used in dissociating. And Du Pont "National" cylinder ammonia is convenient to handle . . . takes up little working and storage space.

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Induction Heating for Better Gears

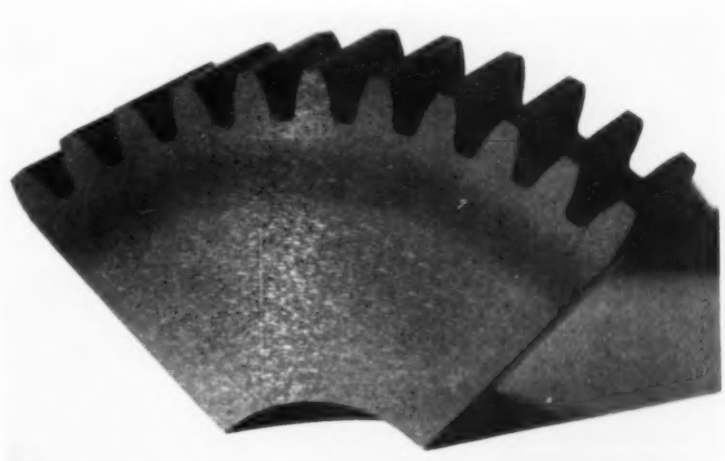
(Continued from p. 110)

Distortion is held to a minimum with this treatment. We have some distortion, but it is small enough that it is not objectionable. Examination showed a pitch-line distortion of 0.0002 to 0.003 in., depending on the size and shape of the part. The bore will change from 0.000 to about 0.003 in. small. All bores do not change, but we have found that splined holes have almost no movement at all. We rebroach all bores to give the gears a uniform bore and also to make the bore concentric with the pitch line. Nothing further is done to the pitch diameter after induction hardening, largely because the distortion is not great enough to be objectionable.

The micrographs shown on p. 110 are typical of the parts in regular production. Figure 2 at left shows the blank heat treated to Rockwell C-26; center shows the transition zone from the body to the root, hardness here ranging from C-36 to 43; micro at right shows the tooth structure, this at C-48 to 50. Figure 3 reveals the depth of penetration of the hardness below the root.

One word of precaution in connection with this method. Working with such high electrical power and the fact that there is no temperature control means special care must be exercised in setting up the power output and time cycle. Someone familiar with elevated temperatures should set up the jobs. Once this has been done, the automatic controls will handle the job.

Fig. 3 — Dark Zone Is Depth of Hardness Penetration Below the Root



Corrosion of Spot Welds in Low-Alloy Steel

(Continued from p. 176)

rust, the crack enters the weld to produce a shear-type failure; if additional stresses are applied, then the cracking may circumvent a portion of the nugget to produce a plug-type failure. In either case, cracking occurs by preferential attack along the dendritic planes in the weld structure.

Rate of corrosion failure of the low-alloy steels generally is proportional to the size of the welds. The effect of an external stress applied as a bending load has negligible effect on the corrosion rate, the same being true of externally applied shear load, except in the case of undersize welds made with low currents. Apparently residual internal stresses resulting from the rapid quenching of the weld are high enough to induce stress-corrosion cracking without an external stress. Corrosion fatigue probably plays an important part in the failure of spot welds in service, but it is impossible to determine this in the flexural-type fatigue test.

(Continued on p. 180)

Corrosion of Spot Welds in Low-Alloy Steel

(*Continued from p. 179*)

In spot welds that join stainless steel to low-alloy steel, the highly alloyed weld nugget reduces the rate of corrosion cracking to some extent, but does not prevent it. However, when fusion welding was used to join these dissimilar metals, there was no sign of corrosion cracking after 4½ years of exposure.

The 17-year research program behind this report was instrumental in the development of specifications for effective weld-through primers and sealers. Primers are defined as coatings applied to sheet metal prior to spot welding which enable the joint to be welded without affecting weld quality and which offer corrosion inhibition to the coated faying surfaces. Sealers are also applied prior to welding and act as a viscous barrier in preventing corrosion environments from reaching the faying surfaces. Sealers likewise may provide chemical resistance to corrosion.

A. H. ALLEN

Metallurgical Research in America*

IN THE JANUARY 1953 issue of *Fonderie*, Georges Blanc, research director for the Foundry Institute of France, gives his impressions of research in metallurgy in the U. S. as acquired during the tours and conferences connected with the 's First World Metallurgical Congress. The first part of this lengthy review comprises a well-illustrated description of the equipment and general aims of the numerous laboratories which the group visited. M. Blanc concludes with a summary of the problems under investigation and the general plan of operations and attack. While he makes no direct comparison between American and French methods, it may be assumed that the bulk of his comments are about matters wherein notable differences exist in the two countries.

He notes a considerable amount of "disinterested scientific research"

(*Continued on p. 182*)

*Digest of "Scientific and Technical Research in Metallurgy in the United States", by Georges Blanc, *Fonderie*, Vol. 84, January 1953, p. 3251-3264.

The Fable of

"The Cat and the Fox"

carries a lesson for Cutting Fluid users

***The Fable . . .** with apologies to Aesop!*

"I am so smart", bragged the Fox to the Cat, "that I know a hundred tricks to escape a pack of dogs."

"Alas", said the Cat, "I know but one way of escape."

"Poor you, too bad you're not as clever as I am", the Fox answered, scornfully.

Just then a pack of hounds came over the hill headed right for the Cat and the Fox. The Cat took to a tree, its lone, but sure, way of escape. And, the Fox? Despite its hundred tricks of evasion, it was finally caught and killed.

The Lesson . . . .

Like the Cat in Aesop's fable, a cutting fluid that best meets a given set of conditions will prove most successful in the long run. A cutting fluid designed to do a hundred jobs may not be the best answer to any. By recommending the cutting fluids best qualified to meet *your* requirements, D. A. Stuart Oil Co. saves you time, money and materials, gives you the optimum relationship between finish, tool life and output on every machining job.

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Metallurgical Research in America

(Continued from p. 180)

and was told that its quantity is growing constantly." This is within the realm of solid-state physics and physical metallurgy, the thermodynamics and equilibrium of refining reactions, heat flow and refractory materials, and surface phenomena related to corrosion. He also calls attention to the large quantity of more "applied research" on such things as creep resistant magnesium and aluminum alloys, boron steels, spheroidal iron and titanium. Fabrication processes – especially welding – engage large numbers of researchers. Much experimentation on metallurgical processes is being done on a pilot-plant scale. [From here on the words are M. Blanc's.]

Work Methods – It is obvious that greatly diversified methods must be applied to this great variety of problems. No generalization can be made on how the various problems are initiated because of the diversity of the organizations. Sometimes most of the initiative is left up to the researchers; in others, an elaborate system of committees sets up detailed programs and time schedules. In those organizations specializing in research, the program is laid out according to the requirements of the sponsors financing the work. However, these organizations also undertake important lines of study on their own initiative. In departments maintained by manufacturing corporations, the programs are usually established by conference between the research director, the production management and the sales department.

Certain laboratories do not distinguish so much between fundamental and applied research as between long-term work and short-term work. Never, in principle, is short-term work assigned to researchers who have responsibility for long-term work who really need a freedom hardly compatible with the execution of daily chores whose cadence is altogether different. It sometimes happens also that a new material or piece of advanced equipment might be assigned to one researcher to see what he can determine by successive experiments without being restricted to any particular program.

Group Experimentation — One is impressed, during the course of a trip around the United States, by the importance attached to group experimentation. The entire personnel often take some part in studies of a scientific or semi-industrial character and consequently can bring to bear abundant practical experience and varied viewpoints. *Experimentation,* however, is the basis of conclusions.

By multiplying experiments, each one with modifications of various factors, a fabric of numerical results is sought of sufficient breadth so that interpolation can be made with a minimum of risk and extrapolation is less likely to be needed.

The attitude of the American researcher is frequently one of never considering anything finally proven. He is ready to start all over again, from the beginning, on a suspected phenomenon. He believes that, by by using a new measuring apparatus to study an already known phenomenon, he can often discover some previously unnoticed mechanism or explain what formerly seemed to be an anomaly.

To operate on these lines, considerable personnel and materials are required but the expenses are justified if they avoid trial and error and result in less trouble when transferring the results to practice, or if they discover products or processes that less profound experimentation would not have revealed.

Execution of Experiments — Division of the work among the personnel is most varied.

In certain laboratories, researchers themselves do everything — observe every detail and modify experimental conditions whenever they consider it worthwhile. Abundant material is put at their disposition to avoid the least delay.

In other laboratories, on the contrary, researchers are relieved of certain tasks which can be grouped in specialized laboratories, but even in this case these operations are more and more frequently assigned to a person with technical or scientific qualifications such that they can understand the meaning and goal of the work undertaken.

In general, organization of the work is adapted to the type of research pursued as well as to the aptitudes of the staff — even when that leads to installing in the same labo-

(Continued on p. 184)

Metallurgical Research in America

(Continued from p. 183)

ratory or in neighboring laboratories duplicates of the same expensive pieces of specialized apparatus.

Laboratory Equipment – Material put at the disposition of the research worker is usually very abundant; almost everywhere – far from dreading a waste of material – everyone wants to avoid loss of time resulting from insufficient equipment.

Collaboration – Americans attach prime importance to collaboration of the staff within the same institute, collaboration among societies of a single group and the laboratories of this group – and even cooperation between firms within an industry.

We were particularly interested in the attitude which management takes concerning attendance of the personnel at meetings, conferences and congresses outside the laboratory. Certain of our British colleagues think that the present multiplication of such meetings wastes time. But from America we got quite a contrary answer.

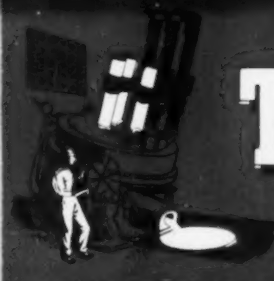
The research director for a large industrial corporation, describing the principles that guided his firm in the organization of its research work, declared that his main preoccupation was to make research workers willing to talk freely to each other and to pool the results of their experience, their experiments, their projects and their methods of work.

The Mellon Institute attributes a part of its success to the exchange of views made possible by the presence in the same building of researchers on different projects.

A large metallurgical group organizes frequent meetings for the personnel of laboratories and of plants, in spite of a wide dispersion of activities geographically; moreover, its publication policy is very liberal, the management considering that technical magazines are still the best means of communicating research results to men in the plants.

Research personnel in laboratories maintained by industrial corporations are in contact with the firm's commercial representatives and so have an idea of what the consumer wants. From this comes fruitful suggestions for laboratory work.

(Continued on p. 186)



Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

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INTRODUCING BEARCAT TOOL STEEL

Super Shock-Resisting ... Versatile, Too!

Here's a brand-new tool steel that we've been developing over the past several years. Proven in a wide variety of production tools and dies, Bearcat is a general-purpose steel especially suited for uses where shock-resistance, hot-work properties and easy machining are important.

Some of Bearcat's big features:

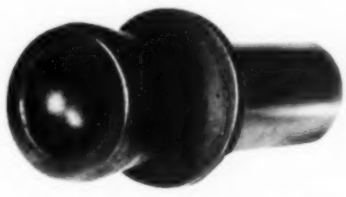
- Super shock-resistance
- Deep hardening . . . in air
- Easy to machine (Brinell 197 max)
- Low distortion in heat-treatment
- Good hot-work properties
- Easily carburized for long wear

These are not just claims made for a new, untried steel! Bearcat has been thoroughly tested in applications such as rivet sets, hot gripper dies, punches, chisels, moil points, forming dies. All of the possible uses for Bearcat have not yet been explored, but we expect it to be ideal for hot headers, blanking dies, master hobs, machined-cavity molds, and many general-purpose tools and dies.

Bearcat is stocked in our mill depot and it's also available through your local Bethlehem tool steel distributor.

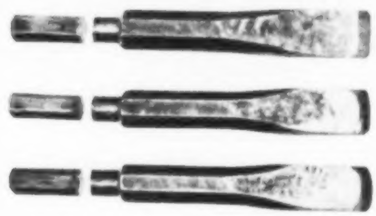
Typical analysis:	C	Mn	Si	Cr	Mo
	.50	.70	.27	3.25	1.40

Complete data may be had by writing us for Booklet 341. Address your request to Room 1037, Publications Dept., Bethlehem Steel Co., Bethlehem, Pa.



BEARCAT DRIVES 27 TIMES MORE HOT RIVETS

Here's one example of what Bearcat can do on a job that calls for both shock-resistance and good hot-work properties. This typical rivet set, made from Bearcat, drove 43,094 rivets and was still in good condition. Rivet sets made from carbon tool steel, and used under similar conditions, drove an average of only 1566 rivets before recupping was required.



All of the chisels broke in service at the sharp change of section. While this is classed as a mechanical error, it does show how improper design can cause failure no matter how carefully a tool may be heat-treated.

Chisel Breakage Cured by Undercutting Shanks

A large user of chisels—made from a top-grade shock-resisting steel, Bethlehem Omega—reported excessive breakage. One of our metallurgical sleuths soon put his finger on the trouble.

When the hexagon shanks were milled by the customer, a milling cutter was used which did not have an adequate radius. As a result, stresses were concentrated at the sharp change of section in the shank. Subjected to heavy impacts in air hammers, the chisels broke prematurely—and always at this portion of the shank.

The solution for the breakage was one that really surprised the customer. See photographs below.

This shank shows the "stress raiser," caused by the lack of sufficient radius, where the milled hexagon section meets the round section.

All of the unused chisels were salvaged by having an undercut ground on the shanks so that a ½-in. radius was provided at the source of the trouble. Despite the smaller section, these chisels gave good service. The sharp change in section was eliminated, stresses were better distributed.

THE BETHLEHEM TOOL STEEL ENGINEER SAYS: High-Carbon Tool Steels Can Be Carburized

Many people don't realize that carburizing can be accomplished with the high-carbon, high-chromium steels—such as our Lehigh H, which contains 1.55 pct carbon and 11.50 pct chromium. The carburizing of tools made from such steels can be either helpful or harmful, depending upon whether the carburized case is produced intentionally or accidentally.

Tools intended for light loads and long service, such as lamination dies, are often intentionally carburized before quenching. Such dies have greatly improved resistance to wear because of the carbon added to the wearing surfaces. The usual procedure is to use carburizing compound as a packing medium and heat for the normal length of time at the quenching temperature.

Sometimes an accidental carburized case results when "spent" carburizer is used as a protective packing medium when heating for hardening. Spent carburizer is often almost as active as new carburizer. An accidentally produced carburized case is not always harmful. It may even be helpful. But there are many heavy-duty tools and dies that will develop chipped or spalled edges if they become carburized. When treating tools of this type, use cast-iron chips as a packing medium during hardening.

Metallurgical Research in America

(Continued from p. 184)

Finally, inspection visits, always welcome with no thought of reciprocal treatment, are also a manifestation of this desire to establish contacts between various groups.

This state of mind mitigates the drawbacks that could result from secretive research done by private organizations in a competitive economy. Secrecy would profit only a small number of producers; the same work would then have to be done simultaneously in several localities.

Finance – The extent of present research in the United States involves important financial problems. According to a report in *National Science Foundation*, sums spent in the United States for research have more than tripled in the last 10 years.

The part taken by public funds in this financing of research has increased seven-fold since 1941 whereas estimated appropriations by industry have little more than doubled. However, the sums allocated by certain corporations are by no means niggardly. According to an eminent French authority, it is not rare for large American enterprises to allocate 5 or 6% of their budget to research and to consider this enormous percentage as a necessary element of cost price, in the same category as, for example, retooling.

Cooperative research achieves, alongside of private research, what the Americans consider to be the key to production – namely, a proper proportionality between free competition and cooperation on the professional level. The considerable advances made in the course of recent years by institutes specializing in research proves actually that in the United States research pays.

Radioisotopes in Metallurgy*

Applications of tracer techniques have developed so rapidly in number that all I can hope to do is give a few of the newer examples.

Starting with the problem of raw materials, there is some hope that nuclear properties of metals themselves will assist in the concentration of metallic values from ores. An example is the ore of beryllium in which the mineral beryl occurs usually as large blue crystals which can be sorted – a method which is neither efficient nor economical, especially for United States' deposits without the characteristic color. Since beryllium instantaneously emits neutrons when bombarded by gamma rays from radium, a Van de Graaff generator, or a radioactive isotope like Sb^{124}, a thin stream of lumps can be moved past this radiation, and an electronic circuit which will detect the emitted neutrons can kick the beryllium-containing piece of rock to one side.

Although radioisotopes have not as yet been applied directly to metal production, they have proved to be of great value in the study of the flotation process – flotation being a method of separation based on the

*Digest of a paper by H. R. Spedden, Union Carbide and Carbon Research Laboratories, Inc., Niagara Falls, N. Y., presented at the "Nuclear Science in Industry" session at American Association for the Advancement of Science, St. Louis, Dec. 29, 1952.

varying affinity of minerals for air bubbles. Of vital importance is detailed knowledge of the surface chemistry of minerals in aqueous suspensions, and the behavior of reagents which produce water-repellent films. Research has already shown that surface layers of flotation reagents are effective when as little as 1% of the area of a mineral is covered with a layer about one ten-millionth of an inch thick. Furthermore, the molecules or ions of this fractional layer are usually in a state of actively trading places with other ions in solution, or are moving laterally across the surface. These are important pieces of information which contribute to our general understanding of flotation and thus will indirectly result in better mineral treatment.

Perhaps the most profitable use of radioactive isotopes in metallurgy has been in the field of research dealing with the segregation of minor constituents in alloys and the distribution of trace impurities.

The basic tools of physical metallurgy — microscopy and X-ray analysis — have been augmented by autoradiography and tracer analysis. A comprehensive review of this development has recently been presented by M. B. Bever, associate professor of metallurgy, Massachusetts Institute of Technology, in the book "Modern Research Techniques in Physical Metallurgy".

One of the earliest uses of radio tracers was by the German metallurgist Tammann in 1932 who studied the solubility of radioactive polonium in various metals. The polonium was concentrated at the grain boundaries, and the actual solubility in the metal crystals was of a much lower order. More recent studies have been made on the distribution of polonium in nickel-manganese-polonium alloys designed for use as pre-ionizing spark plug electrodes.

Some late structural investigations have been of cast aluminum alloys containing from 2 to 5% copper. In an alloy containing 3% copper, including a radioactive copper isotope, the copper content varied from 2.2% in the cores of the dendrites to 3.8% in the interdendritic regions, as shown by an autoradiograph of a polished cross section.

The phenomenon of diffusion — particularly self-diffusion — is of great interest in studying metals under stress at high temperatures.

Of fundamental importance also to many problems in metallurgy and geology is a knowledge of diffusion in mineral crystals. Studies on chalcocite (Cu_2S) at room temperature brought out the rather surprising result that copper atoms may move quite freely throughout the crystal lattice whereas sulphur atoms are rigidly immovable. This is in accord with what is known of the spacing of the atoms within the lattice and may well be related to the semiconducting properties of Cu_2S.

Powder metallurgy is one of the newer techniques in preparing metal parts. Its optimum use depends upon the proper solution of problems concerning size distribution and shape of the particles, surface contamination, atomic diffusion during sintering, and control of porosity in finished parts. One of the most promising fields of application is for electronic devices. For example,

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Radioisotopes

(Continued from p. 187)

the properties of magnets made from iron, nickel, and cobalt powders, plus a suitable carbon content, depend on the size of the individual metal particles, as well as the particle size distribution. This is particularly true for devices in the high-frequency and ultra high-frequency field, such as radio and television. In the range of about 10 to 50 megacycles, for example, iron particles having a diameter of 3 to 4 microns or less perform satisfactorily, whereas particles larger than about 8 microns are relatively useless.

One method of producing these fine powders is by the decomposition of a metal carbonyl vapor in a heated vessel into carbon monoxide gas and finely divided metal. A large range of sizes depending on the phenomenon of nucleation and crystal growth must be subsequently separated. A patent has recently been granted to J. M. Lambert (No. 2,604,442) on a process for increasing the number of nuclei by the use of radiant energy so that a greater number of crystals will be formed and none will have the opportunity to grow beyond the very limited size range of about 3 to 7 microns. Whereas formerly 1 lb. of vapor would decompose into approximately 500 billion particles, and half of the weight of this powder would be composed of particles too large for use, radiant energy forms about 4000 billion particles from the same pound of vapor and the problem of oversized particles is nonexistent. The radiant energy which works this miracle may be gamma, beta, or ultraviolet radiation or high-energy particles from a radioactive isotope placed adjacent to the inlet tube or suspended within the decomposition chamber.

Much of the recent progress has stemmed from the availability of approximately 100 different isotopes from the Oak Ridge National Laboratory. In addition to supplying isotopes for research, the laboratory irradiates samples of materials supplied by industry, and also provides multicurie sources which enable any industry to use high-energy radiations in its own plants.

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to replace previous oil that was causing deterioration of gaskets and packing of the injection molding machine shown here.

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Constitution of Fe-Ni-Cr Alloys*

A PAINSTAKING investigation of 66 iron-chromium-nickel alloys was carried out in four research laboratories in England. Attention was directed particularly to the occurrence of the sigma phase in various alloy combinations in the range of 1020 to 1475° F. The National Physical Laboratory, Brown-Firth Research Laboratories, English Steel Corp. and Central Research Laboratory of the United Steel Co. participated in this project, which began five years ago.

The 66 alloy combinations were prepared from high-purity iron, nickel and chromium, and were melted under dry hydrogen in thoria-lined crucibles in an induction furnace. All of the ingots were then homogenized by soaking at 2460° F. for three days and quenched from 1830° F. Samples from each melt were annealed at temperatures between 1020 and 1475° F. for times up to 590 days; all annealing was done in sealed and evacuated silica tubes followed by water quenching.

Additional powdered samples for X-ray examination were also annealed in sealed silica tubes for periods up to 700 days at the same temperatures as the lump samples.

Small slices of alloy cut from the heat treated ingots were alternately cold rolled to 50% reduction and annealed at 1020° F. until no further structural change took place. This phase of the research resulted from the early observation that the rate at which sigma phase is precipitated increases about 1000 times if the alloy is severely cold worked before annealing.

The nickel content of the alloys varied from 1 to 50% and the chromium from about 10 to 40%. This wide range of composition yielded structures before annealing which were entirely ferritic, entirely austenitic and mixed ferritic and austenitic. The samples were annealed for various times at 1020, 1200 and 1475° F. in an attempt to observe whether a final equilibrium structure might be determined. It was found

(*Continued on p. 192*)

*Digest of "The Constitution of Iron-Nickel-Chromium Alloys, 550°-800° C.", by A. J. Cook and R. B. Brown, *Journal*, British Iron & Steel Institute, Vol. 171, August 1952, p. 345-353.

Constitution of Fe-Ni-Cr Alloys

(Continued from p. 190)

that the rate of precipitation in the strain-free alloys was extremely slow. The cold worked samples were therefore exposed for similar periods and temperatures because the rate of transformation of the different phases was so much more rapid. It was also found that the first precipitates were so fine that no microscopic distinction between the alpha, gamma, and sigma phase was possible. Longer exposure periods, prior cold working of samples, and X-ray examination were necessary to determine accurately what phases existed in any given structure.

At 1020° F. the changes in structure were sluggish and the precipitates were very fine, even after 700 days' exposure. In general, the ferritic alloys containing more than 20% Cr and less than 3% Ni remained in the alpha phase, some faint trace of sigma was found by X-ray examination in those alloys containing 25% Cr, and large amounts of sigma precipitated when chromium content exceeded 30%.

The alloys of mixed alpha and gamma phase which contained to 14% Ni and 15 to 20% Cr showed little change in structure, although slight precipitation of sigma was observed in these two-phase alloys, especially in the cold worked specimens. The X-ray patterns for this series showed $\alpha + \gamma + \sigma$ present after all treatments, but the visual determination of sigma phase in the microscope was not reliable.

As the nickel content rose above 15% the alloys became entirely austenitic, and no sigma phase was detected even though the chromium content reached 33%. After long exposure, precipitates appeared in the austenitic grains; X-ray studies showed that this precipitate was always the alpha phase.

Three ternary diagrams are included in the paper which show the phase boundary lines for the various constituents at 1020, 1200 and 1475° F. (550, 650 and 800° C.).* Because of the sluggish rates of trans-

(Continued on p. 194)

*Diagrams for 650 and 800° C., taken from earlier work by these and other authors, are included in *Metal Progress* data sheet for August 1952, p. 96-B.

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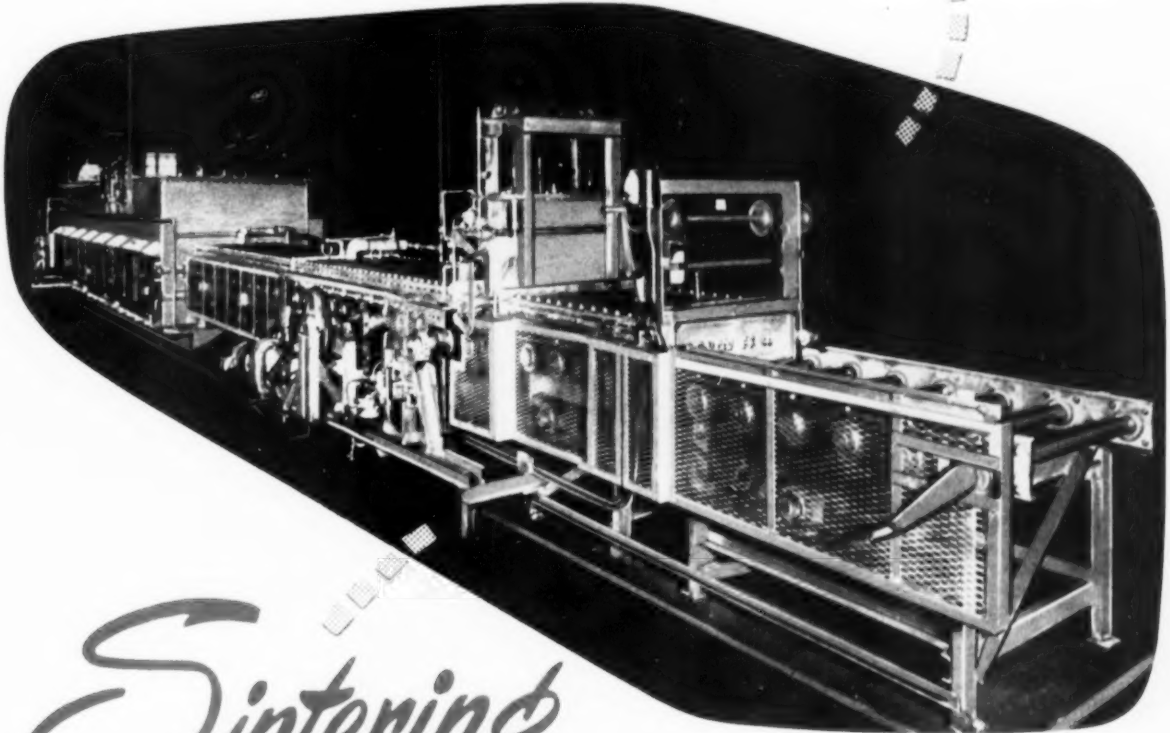

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Constitution of Fe-Ni-Cr Alloys

(Continued from p. 192)

formation found at 1020° F. (550° C.), only dotted boundary lines are placed on this chart. At 1200 and 1475° F. the rates of change were so much more rapid that definite boundary lines could be plotted. These three diagrams give an accurate view of the occurrence of sigma phase at these temperatures.

The paper contains many photomicrographs of the structures observed, a complete tabulation of the chemical analyses of the alloys, and tabulations of the structures observed in the microscope, X-ray identification of the phases present and the lattice parameter of the existing gamma phase.

E. C. WRIGHT

Progress in Temperature Measurements During Steelmaking*

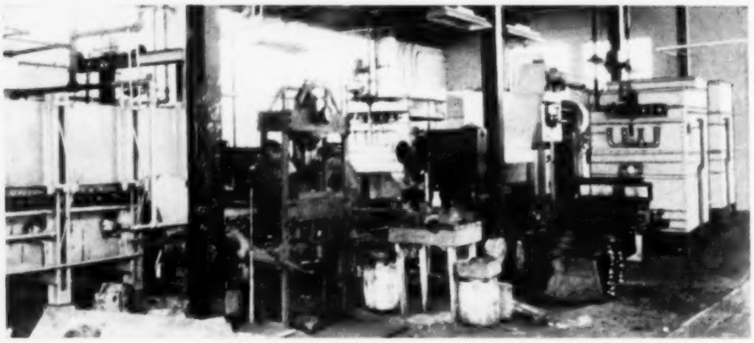
THE SUCCESS of the platinum-platinum + 13% rhodium thermocouple at the Central Alloy District of Republic Steel Corp. is attributed to three factors: *(a)* reliability and stability of such couples, *(b)* fast-acting electronic recorders, and *(c)* the use of fused silica protecting tubes.

Experiences with the use of platinum-platinum plus rhodium couples involved several problems, including the necessity of having adequate specifications for platinum wire for thermocouple use, and the problem of thermocouple wire contamination during service. In the early stages of development of these thermocouples, high losses of platinum wire were experienced – the major factor for the losses being large grain size in the wire. This condition was also associated with a very low tensile strength and poor elongation.

Contamination of thermocouple wire during service was found to be due, in one period of excessive wire breakage, to presence of lead. The

(Continued on p. 196)

*Digest of "Progress on Temperature Measurement", by D. G. Harris, a paper presented in Pittsburgh before the Tenth Annual (December 1952) Electric Furnace Steel Conference of the American Institute of Mining and Metallurgical Engineers.



Progress in Temperature Measurements During Steelmaking

(Continued from p. 194)

lead pickup was on the wire insulators which, in turn, contaminated thermocouple wire. The breaks occurred at the insulator joints. The lead contaminant was finally traced to the refractory cement used on a portion of the couple immersed in the molten steel bath. Analysis of the cement showed that it contained 0.02 to 0.03% lead.

Figures were given for the cost per reading and these are believed to be representative of the industry. Including platinum wire, silica tube, total labor costs and other materials, this cost varies from $0.85 to $2.00.

The question of the straight versus curved couple assemblies is largely governed by personal preference. However, details in design of the furnace play a major role in this choice. For example, the electric furnaces at the Central Alloy District require that the doors be raised for a temperature reading; by using a curved thermocouple the door needs to be raised only a small amount, and this protects the furnace helper from extreme heat. Also, a minimum portion of the curved couple actually comes in contact with the molten steel, and the thermocouple hot junction in the silica tube can be more accurately positioned in the molten bath with less contact with slag and metal. A straight couple requires a better type of material for protection. However, the platinum wire receives better protection in the straight couple.

J. E. Harrod of U. S. Steel Corp., in his discussion of the paper, pointed out that experience at the South Chicago Works over the past five years closely parallels that of Republic Steel Corp. Investigations have shown temperature gradients present in the molten steel bath, particularly with stainless steel heats. A 9-in. immersion thermocouple has been used, and also a special couple that can measure to levels as deep as 25 in. Gradients observed ranged from 10 to 120° F. in the bath. Temperature during the oxidizing period is uniform; it is after chromium reduction from slag and dur-

(Continued on p. 198)

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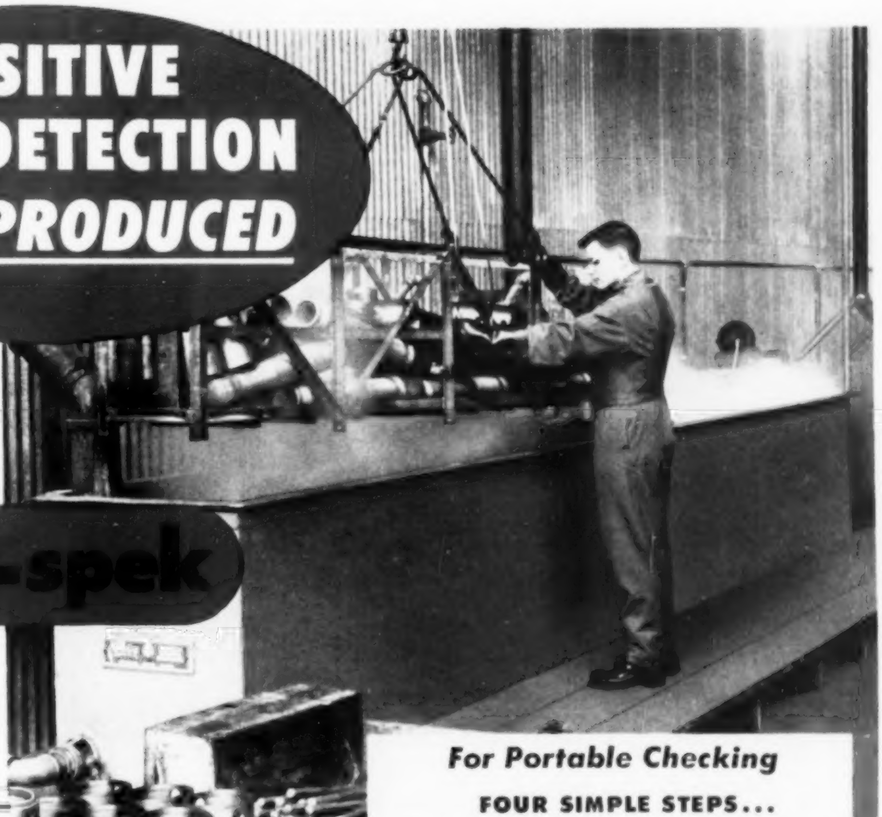

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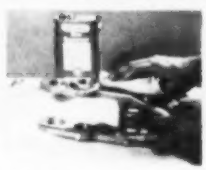
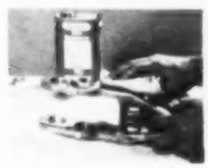


STEP 1: Clean surface

STEP 2: Apply Dy Chek Dye Penetrant



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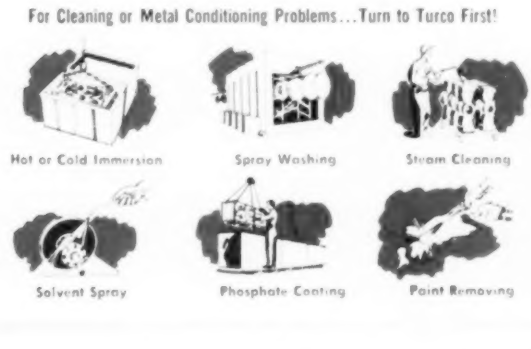

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Progress in Temperature Measurements During Steelmaking

(*Continued from p. 196*)

ing finishing periods that temperature gradients develop. Stirring of the bath can be used to equalize temperature prior to thermocouple reading. It was also observed by Mr. Harrod that thick and fluid slags give difficulty by covering the thermocouple tips with slag and burning the thermocouple wires. It is claimed that it is impossible to use the immersion thermocouple as the sole method for temperature measurement; it is not yet accepted as a uniform production tool.

Thermocouple experience at Atlas Steels, Ltd., Welland, Ont., was described by L. Barnhardt. Small couples are used on spoon samples rather than the larger bath types, the spoon sample averaging 70 to 100° F. lower than the temperature reading in the furnace. Some 400 readings of this kind are taken each month, with three to four readings per protection tube. It was emphasized by G. Zipf, Babcock & Wilcox Tube Co., that stirring must precede the thermocouple reading for best results. The factors of ingot mold cost, refractories and steel quality should also be evaluated in estimating cost of thermocouple readings, since reading costs can be drastically affected by these factors.

S. W. POOLE

Quench Aging of Iron*

THE PRECIPITATION of carbon from a supersaturated solution in alpha iron is a much more complicated process than has been indicated by previous work during the past 20 years. Newer techniques such as X-ray diffraction and the electron microscope, combined with the older method of studying the aged structure in the optical microscope, show that the precipitation or aging phenomenon in low-carbon ferrite (α-iron) is very similar to that which occurs in the tempering of high-carbon martensite.

(*Continued on p. 200*)

*Digest of "The Quench Aging of Iron", by Anna L. Tsou, J. Nutting and J. W. Menter, *Journal* of the British Iron and Steel Institute, Vol. 172, 1951, p. 163-171.

Quench Aging of Iron

(Continued from p. 198)

The research consisted of reheating samples of ingot iron, after quenching to dissolve the carbon and nitrogen, to 212 to 1112° F. in steps of 180° for various periods of time. Hardness measurements were made and the structures developed were studied in the light microscope, electron microscope and by X-ray diffraction.

The material analyzed 0.026% C, 0.0057 N, 0.02 Si, 0.05 Mn, 0.035 S, 0.004 P, 0.038 Ni, and 0.05 Cu. Cr, Mo, W, Ti, Co, Al, Sn, Pb were less than 0.02% each.

The iron was heated to 1290° F. for 2 hr. and quenched in ice water. Half-inch cubes cut from the quenched bars were then aged at 212, 392, 572, 752, 932 and 1112° F. respectively for different times.

Aging at 212° F. – Hardness measurements showed a gradual increase from Vickers 102 to a maximum of 116 after aging for 60 min. After this peak the hardness gradually decreased to about 100 at the end of 5 hr. and showed no further change up to 50 hr. No change in microstructure was apparent until the maximum hardness was reached, when a mottled background structure in the grains was revealed. In the electron microscope these asperites were so small that they were estimated to be of the order of 300 to 500 A in diameter. At the end of 5 hr. at 212° F. all of the grains exhibited these asperites, and their size had grown in a platelet or disk shape of about 500 A thick and 2000 to 3000 A in diameter.

Aging at 392° F. – The maximum hardness of Vickers 114 was reached in 5 min. The hardness then decreased rapidly to 100 in 30 min. and reached a constant minimum value of 90 for all aging times between 1 and 40 hr. The structure after 5 min. was quite similar to that described above for 1 hr. at 212° F. Longer aging at 392° F. induced coalescence of the precipitated particles which could be readily seen in the light microscope. After 15 hr. the plate-like precipitate was found to be uniformly distributed throughout the ferrite grain and was estimated to be about 2500 A thick and 8000 to 10,000 A in diameter. The mean volume of

(Continued on p. 202)

Quench Aging of Iron

(Continued from p. 200)

the precipitate after 15 hr. at 392° F. was about 35 times greater than that formed after 100 hr. at 212° F.

Aging at 572 to 1112° F. – No hardness increase was noted at these temperatures because the overaging effect set in quite rapidly. Precipitation and particle growth took place very rapidly, and no mottled asperite grain structure developed. Particle growth stopped after 30 min. at 572° F. and in lesser times at higher temperatures. The particles seen after 30 min. at 572° F. had the same distribution and dimensions as those seen after 15 hr. at 392° F. At 752° F., precipitates were observed both within the grain and at grain boundaries for aging periods of 1 to 16 hr. As aging time increased, more precipitate appeared at grain boundaries, and after 20 hr. all particles within the grains had disappeared.

At 932 and 1112° F. the particles precipitated at random throughout the grains for brief aging periods, and then migrated to grain boundaries as aging time was increased. After 20 hr. at 932° F. the grain boundary particles resembled normal cementite spheroids.

Electron Diffraction Studies – Examination of the original iron as quenched from 1292° F. always showed a diffraction pattern of α-iron and also a face-centered lattice with $a_o = 3.63$ KX whenever the sample was etched with nital. When the specimens were abraded with 000 emery, the diffraction rings showed only the α-iron lattice, indicating that the nital etch was developing a structure in relief which was of austenitic character. In order to check this anomaly a sample of very pure iron, containing less than 0.002% carbon and 0.002% nitrogen, was quenched and etched with nital. This diffraction pattern showed no evidence of austenite.

Two samples aged at 212° F. showed the same diffraction pattern as those quenched from 1292° F. A specimen aged 15 hr. at 392° F. exhibited both α-iron and austenite patterns and, in addition, a further set of rings typical of the hexagonal structure of ε-iron carbide described by Jack in his study of the decomposition of martensite at 250° F.;

(Continued on p. 204)

Quench Aging of Iron

(Continued from p. 202)

the lattice spacings were in good agreement with Jack's results. Samples aged at 572° F. and above showed no evidence of the hexagonal carbide precipitate; all of the precipitates were of the normal orthorhombic type of Fe_3C.

Summary of Results – It is seen that quench age hardening of iron can result from the precipitation of a carbide from a supersaturated solution of carbon in α-iron. When aging at 212° F., maximum hardness occurs after 1 hr.; particles about 300 to 500 Å in diameter have been detected with the electron microscope. At 392° F., the maximum hardness is reached in 5 min., and, with further aging, the plate-like precipitates increase in size and form preferentially at the subgrain boundaries within the ferrite crystals. By electron diffraction, it now becomes possible to identify the structure of the precipitate as ε-iron carbide. At 572° F. and above only cementite (orthorhombic Fe_3C) was observed.

Iron specimens with a total carbon content of 0.026%, of which 0.015% is held in supersaturated solution by quenching from 1292° F., have been found to contain austenite as a grain-boundary film. Its composition was estimated to be 0.85 to 1.7% carbon or 1.7 to 2.33% nitrogen, but it is thought to be a mixed carbon-nitrogen austenite.

E. C. WRIGHT

Hot-Stage Microscopes*

THE PRODUCTION of still and motion picture micrographs (in black and white, and in color) of molten materials, as well as metals heated below their melting point, is becoming regular practice. Some of the difficulties in photographing metals and alloys at temperatures below their melting point are described in this article. Attention is drawn to the need for melting in vacuum or in special atmospheres to avoid surface oxidation. A warning is given

(Continued on p. 206)

*Digest of "Uses of the Hot-Stage Microscope", by P. J. E. Forsyth, *Journal* of the Institute of Metals, Vol. 81, February 1953, p. 150-151.

Hot-Stage Microscopes

(Continued from p. 204)

regarding the surface appearance of samples. For example, a leaded brass photographed at 500× at 932° F. showed the lead to have penetrated the grain boundaries; after repolishing, it was found that the lead had only migrated along the surface grooves produced by thermal etching of the boundaries.

The conclusion is drawn that the hot-stage technique for examining metallographic specimens may be very useful for investigating recrystallization and boundary migration, for detecting segregation in alloys, low melting-point impurities such as boundary films, and solid phase transformations. Photomicrographs illustrate the article.

H. J. ROAST

Electrically Conductive Glass*

GLASS SURFACES can be made conductors without interfering with their visibility quality by impregnating the glass with tin salts. Glass is obtainable with a nominal resistivity of about 125 ohms per square. (The expression "ohms per square" without any dimension applies when the current enters and leaves along whole opposite sides of a square area of any size.) When a square of typical conductive glass with a side of either 1 in. or 1 ft. in length is placed under 110 volts, a current of 0.88 amp. passes over its surface, equivalent to 96.8 watts. An estimate of the thickness of the tin oxide film is 0.00002 in. The film is not volatile and is not affected by the passing of the current.

Such glass is applicable for windshields for aircraft for the prevention of icing; and in windshields for automobiles in safety glass applications the conductive surface may be placed on the inside of the sandwich to prevent the possibility of electric shock. Glass of this type is made by the Pittsburgh Plate Glass Co., and Libbey-Owens-Ford Glass Co., markets it under "Electropane". The Corning Glass Co. uses it in laboratory glassware.

*Digest of "Surface Conductivity Glass", a note in *Tin and Its Uses*, published by Tin Research Assoc., November 1952, p. 11-12.

AWAKENING TO CASTING POTENTIALS

It is difficult not to rattle-around, like a peanut-in-a-drum, in the "room for improvement", which confronts anyone working to advance Casting Potentials. The total effort so directed is infinitesimal in proportion to the need and promise. Interest and support are increasing.

The Government is spending about a Half-Billion Dollars on forging process facilitation and improvement. The effort and facilitation necessary to up-grade all defense production castings to eliminate 60 to 80% of the machining currently done upon them, and steel castings to replace a large percentage of forgings and a fair percentage of fabrications, would cost, we contend, far less.

Limitations in size and form of forging process, and the geometrical expansion of technical obstacles and capital investment as size increases, become increasingly evident as the "big press - large forging program" proceeds. The inherent strength-to-weight advantage of tubes can be broadly extended to large configurations of "hollow" or "tubularform" design with increasing benefits derived from the use of blended contours and tapering section. The benefits increase with size through continuity. The replacement of many pieces joined together with overlaps and focal stresses by larger pieces with strength and weight distributed to meet service requirements, rather than fabrication methods, should be obvious. Experience, however, has taught that the simpler the concept, the harder it is to sell. Philosophers are more apt to think in fundamental terms than engineers. Most of us seem to enjoy doing things "the hard way". Progress, far beyond the proven progress of a few pioneers, in bridging the very considerable "gap" in physical properties between light metal castings and forgings is considered as *expediently attainable* when *enlightened* and *adequately facilitated* effort is *put to the task.*

No such gap exists between steel castings and steel forgings. There is a wide sector of applications where steel castings can be made with equal physical properties, superior strength-to-weight ratios, and for *superior producibility,* as compared to forgings. Psychological factors, rather than technical considerations, principally retard broader planning for upgrading and casting process and increased use of castings with great benefit to National Defense. Large savings to the taxpayer will inevitably result from pouring metal *directly* to close approximations of final form.

Scientific fact and soundly projected engineering *cannot be altered by lack of understanding.* Such lack, however, can *long defer its acceptance and effective employment.*

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

The work of William T. Bean in stress evaluation, applied to stress-engineered casting design, is effectively converting configurations made of "bits-and-pieces" into integrally cast, highly stressed parts with reduced weight and functional improvement.

AUTOMOTIVE ANGLES . . .

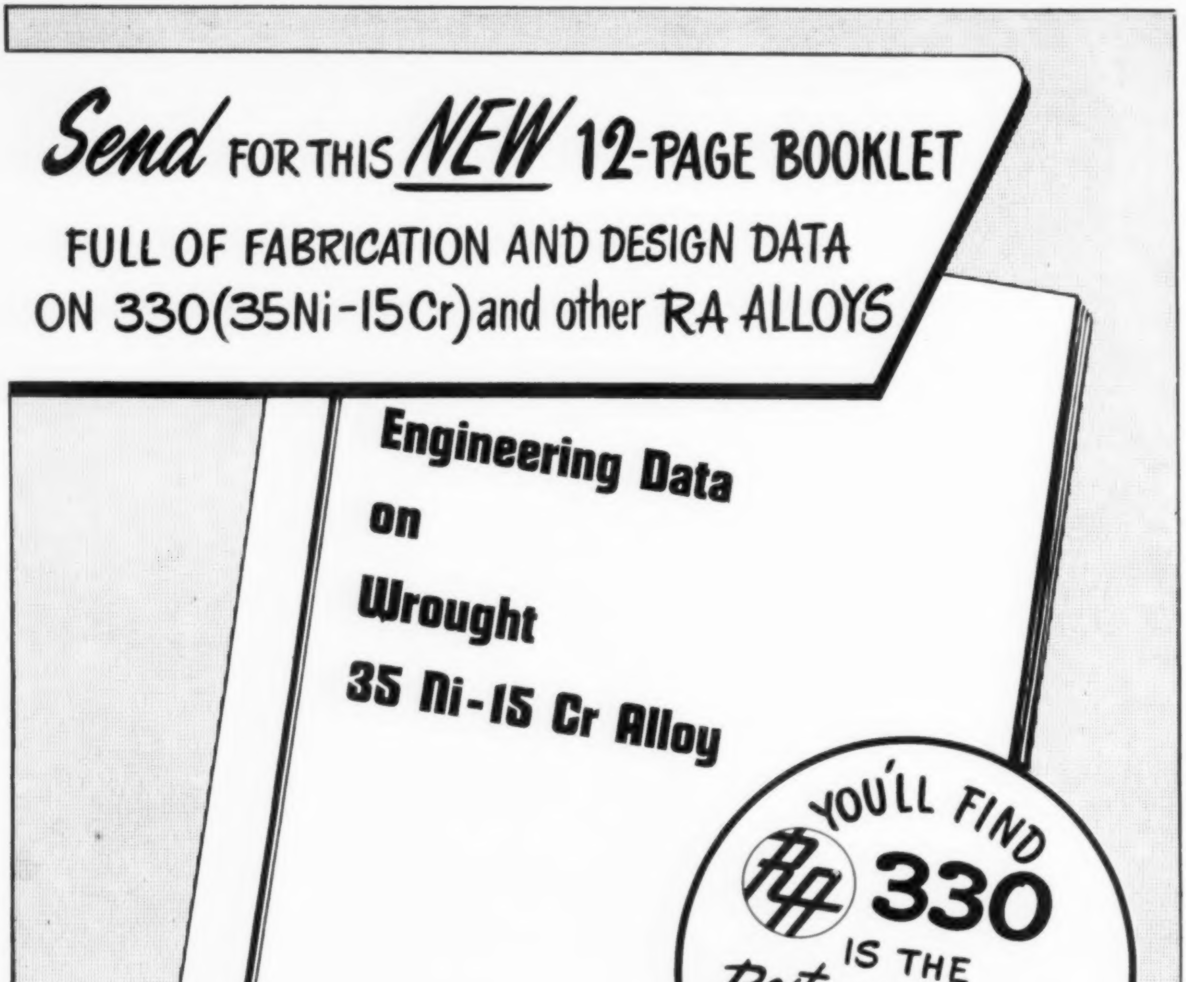
Don't confuse the "chopped" convertible having conventional springing, braking and nose-heavy weight distribution with true Sports cars. Their controls, springing and braking, designed to couple maximum safety with high speed performance, are greatly inferior to road race-bred Sports cars. A chassis designed to function admirably under the family sedan is a different animal that any competent engineer in Detroit, or overseas, would put under a high performance "sports car".

Detroit's chrome-draped-jumbo "Sports Models" are market feelers. If sufficient market exists for *truly functional sports cars,* Detroit will build them *better, cheaper,* and *faster* than anything from Europe, except some hand-made race jobs with custom bodies, and built-in "temperment."

Several "Jr." Allards, like the photo above, will be run in the LeMans and other European road races powered with Cadillac engines, souped to 330 horsepower. (They are also available with Ford and Chrysler engines.) The Allard is a "progressively refined semi-production hot-rod incorporating many altered Ford parts". The one shown weighs only 2200 lbs. net. Near-future U.S. *true sports cars* will be an acceptable compromise of race-car performance with *U.S. concepts of comfort and durability.* A most *acceptable ingredient* will be *dependable U.S. dealer service.* Anyone who has had experience with service on foreign cars in U.S., such as Jaguar, will appreciate a piece of honest "Detroit Iron", complete with U.S. *metallurgy and dependability,* and *maintenance.* It is interesting to hear the alibis (none of which come from Rolls-Royce) for Rolls' adoption of G.M.C. hydramatic as standard equipment. The engineering integrity and excellence of Rolls-Royce has never been seriously questioned. Rolls' reputation has lent glamour to other British automotive production for the "export market" which cognizant British motorists would gladly swap three-to-one for any one of the U.S. "low priced" cars. Anyone curious as to the standing of U.S. cars in England should note the high advertised British prices for pre-war U.S. cars.

It is satisfying that both English and Americans respect each other's engineering and craftsmanship, and share jointly in the automotive *advance.* It is hoped that British persistence in courting enemy trade will not prove their undoing in U.S. markets, and in U.S. credits!

An "aditorial" by the President of General Alloys Company, Boston, U.S.A., "oldest and largest exclusive manufacturer of heat and corrosion resistant alloy castings".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METAL PROGRESS

Volume 63; January 1953 to June 1953

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Subject Index for Vol. 63

The subject headings used in this index are chosen in accordance with the ASM-SLA Metallurgical Literature Classification, published by the American Society for Metals, 1950

(aa) Atomic Age; *(b)* Biography; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Digest; *(ds)* Data Sheet; *(sr)* Short Runs.

Author Index

***(aa)* Atomic Age; *(b)* Biography; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Digest; *(ds)* Data Sheet; *(sr)* Short Runs.**

Invitation to Entrants

8th metallographic exhibit

Entries are invited in the 8th Metallographic Exhibit, to be held during the National Metal Exposition in Cleveland the week of Oct. 19 through 23, 1953. Entries will be displayed to good advantage and awards will be given for the best micrographs as decided by a competent committee of judges.

CLASSIFICATION OF MICROS

1. Toolsteels and tool materials
2. Stainless steels and heat resisting alloys
3. Other steels and irons, cast or wrought
4. Aluminum, magnesium, beryllium, titanium and their alloys
5. Copper, nickel, zinc, lead and their alloys
6. Metals and alloys not otherwise classified
7. Series showing transitions or changes during processing
8. Welds and other joining methods
9. Surface phenomena
10. Results by unconventional techniques (other than electron micrographs)
11. Slags, inclusions, refractories, cermets

RULES FOR ENTRANTS

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints shall be mounted on stiff cardboard of maximum dimensions approximating 15 by 22 in. (14 by 18 in. for entries from outside U.S.A.). Heavy, solid frames are not permissible because of difficulties in mounting the exhibit. Entries should carry a label giving:

Name of metallographer
Classification of entry
Material, etchant, magnification
Any special information as desired

Transparencies or other items to be viewed by transmitted light must be mounted on light-tight boxes wired for plugging into lighting circuit, and built so they can be fixed to the wall.

Entrants living outside the U.S.A. should send their micrographs by first-class letter mail endorsed "May be opened for customs inspection before delivery to addressee."

Exhibits must be delivered between Sept. 25 and Oct. 15, 1953, either by prepaid express, registered parcel post or first-class letter mail.

Address: Metallographic Exhibit
American Society for Metals
7301 Euclid Ave.
Cleveland 3, Ohio.

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence.

A Grand Prize, in the form of an engrossed certificate, and a money award of $100 will be awarded the exhibitor whose work is adjudged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's headquarters.

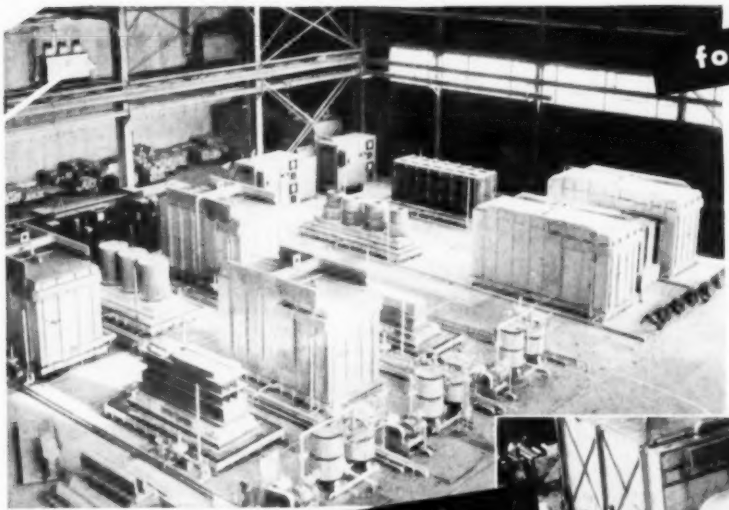
All other exhibits will be returned to owners by prepaid express or registered parcel post during the week of Oct. 26, 1953.

35th National Metal Congress and Exposition

Cleveland, Ohio • **OCTOBER 19 to 23, 1953**

DRYing is a production tool at Pennsylvania Transformer

for a better start...



All core steels are annealed uniformly in these DRY controlled atmosphere furnaces.

Three Lectrodryers* are placed in a production line manner right alongside the furnaces they serve at Pennsylvania Transformer Company, Canonsburg, Pa. They DRY controlled atmospheres as these gases are fed into the furnaces, thereby preventing attack on the core steels being annealed.

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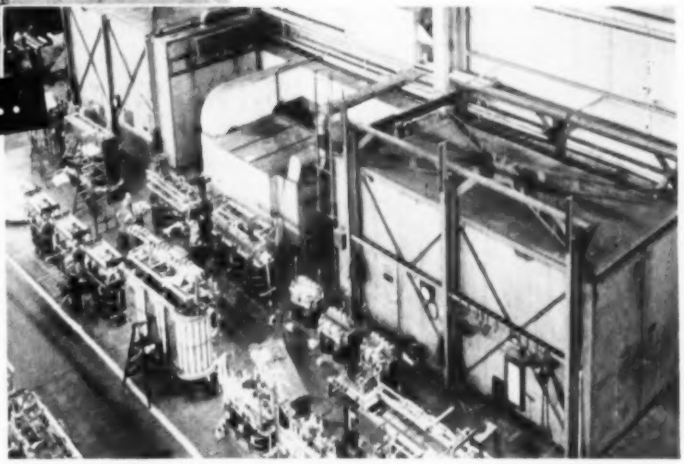

Humid weather, once tough on production schedules, has been tamed by this Lectrodryer.

Again in final assembly, a Lectrodryer is helping to maintain top quality, while also speeding output. It dries the air supplied to these coil drying ovens, making production independent of outside weather conditions. A typical timesaving was a 92-hour drying period reduced to 32 hours.

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